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<b>(21) International Application Number:</b> PCT/US00/15286  <b>(22) International Filing Date:</b> 02 June 2000 (02.06.2000)  <b>(30) Priority Data:</b> 60/137,654 04 June 1999 (04.06.1999) US 60/165,394 12 November 1999 (12.11.1999) US  <b>(60) Parent Application or Grant</b> OXIBIO, INC. [/]; (). GREEN, Terrence, R. [/]; (). FELLMAN, Jack [/]; (). VON MORZÉ, Herwig ; ().	<b>Published</b>	
<b>(54) Title: ANTI-INFECTIVE MEDICAL DEVICE AND PRODUCTION METHOD</b> <b>(54) Titre: DISPOSITIF MEDICAL ANTI-INFECTIEUX ET PROCEDE DE PRODUCTION</b>  <b>(57) Abstract</b>  <p>Methods of providing and/or maintaining anti-infective activity to a medical device generally comprising exposing the medical device to an anti-infective oxidant and transferring the anti-infective oxidant into a wall of the medical device. One embodiment comprises exposing a medical device which is at least in part within a patient to the anti-infective oxidant. Another embodiment comprises exposing a medical device to an aqueous solution which produces the anti-infective oxidant and transferring a sufficient amount of the anti-infective oxidant into the medical device wall to provide the medical device with anti-infective activity. Another aspect of the invention is directed to an oxidant-releasing member which has the anti-infective oxidant releasably contained therein and which is configured to be disposed adjacent to the medical device. Presently preferred medical devices useful in the method of the invention include catheters such as venous, arterial, and urinary catheters, generally comprising an elongated catheter shaft having a lumen extending therein, and optionally having a balloon on the shaft in fluid communication with the catheter lumen.</p> <b>(57) Abrégé</b>  <p>La présente invention concerne des procédés permettant d'obtenir et/ou de maintenir une activité anti-infectieuse à un dispositif médical qui consiste généralement à exposer le dispositif médical à un oxydant anti-infectieux et à transférer l'oxydant anti-infectieux dans une paroi du dispositif médical. Dans une première réalisation, on expose un dispositif médical, contenu au moins en partie à l'intérieur d'un patient, à l'oxydant anti-infectieux. Dans une deuxième réalisation, on expose un dispositif médical à une solution aqueuse qui produit l'oxydant anti-infectieux avec transfert d'une quantité suffisante d'oxydant anti-infectieux dans une paroi du dispositif médical afin de lui conférer une activité anti-infectieuse. Dans une troisième réalisation, on met en oeuvre un élément libérant l'oxydant anti-infectieux conçu de façon à être placé adjacent au dispositif médical. Des dispositifs médicaux préférés utiles dans le procédé de l'invention sont représentés par des cathéters, tels que veineux, artériels, et urinaires, comprenant généralement une tige allongée possédant une lumière sur toute sa longueur et éventuellement comportant un ballon sur la tige en communication fluide avec la lumière du cathéter.</p>		

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(54) Title: **ANTI-INFECTIVE MEDICAL DEVICE AND PRODUCTION METHOD**

(57) Abstract: Methods of providing and/or maintaining anti-infective activity to a medical device generally comprising exposing the medical device to an anti-infective oxidant and transferring the anti-infective oxidant into a wall of the medical device. One embodiment comprises exposing a medical device which is at least in part within a patient to the anti-infective oxidant. Another embodiment comprises exposing a medical device to an aqueous solution which produces the anti-infective oxidant and transferring a sufficient amount of the anti-infective oxidant into the medical device wall to provide the medical device with anti-infective activity. Another aspect of the invention is directed to an oxidant-releasing member which has the anti-infective oxidant releasably contained therein and which is configured to be disposed adjacent to the medical device. Presently preferred medical devices useful in the method of the invention include catheters such as venous, arterial, and urinary catheters, generally comprising an elongated catheter shaft having a lumen extending therein, and optionally having a balloon on the shaft in fluid communication with the catheter lumen.

**Description**

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## ANTI-INFECTIVE MEDICAL DEVICE AND PRODUCTION METHOD

### 5 FIELD OF THE INVENTION

The invention is directed to methods and devices for providing and/or maintaining anti-infective activity to a medical device, and more particularly to methods and devices for transferring anti-infective activity through *in situ* presentation of formulations which generate anti-infective oxidant such as elemental iodine and allow for its transfer to the polymer base of urinary, venous, and other lumen indwelling medical devices, conferring to such devices prophylactic and therapeutic treatment of implant-linked infections, and/or maintaining the dis-infected state of the devices themselves.

### 15 REFERENCES

#### US Patents:

- 4278548 Bettinger et al. (1981) Control of biological growth in reverse osmosis permeators.
- 4312833 Clough et al. (1982) Sterilizing hydrophilic contact lenses.
- 4476108 Kessler et al. (1984) Bactericidal method.
- 4576817 Montgomery and Pellico (1986) Enzymatic bandages and pads.
- 4937072 Kessler et al. (1990) In situ sporicidal disinfectant.
- 5227161 Kessler (1993) Method to clean and disinfect pathogens on the epidermis by applying a composition containing peroxidase, iodide compound and surfactant.
- 5232914 Fellman (1993) Solid, storage-stable, germicidal. Pre-iodine composition.

- 5370815 Kessler (1994) Viscous epidermal cleaner and disinfectant.
- 5419902 Kessler (1995) Method for inactivating pathogens.
- 5462713 Schiltzer et al. (1995) Double redox system for disinfecting contact lenses.
- 5607681 Galley et al. (1997) Anti-microbial compositions.
- 5629024 Kessler et al. (1997) Method of forming an iodine based germicide composition.
- 5772971 Murphy et al. (1998) Iodine-based microbial decontamination system.

Other Relevant Articles:

- Barabas, E.S. and Brittain, H.G. (1998). Povidone-Iodine *in* Analytical Profiles of Drug Substances and Excipients (ed., Brittain, H.G.) Vol. 25, AP, San Diego, pp. 341-462.
- Birnbaum, L.M., Hopp, D.D. and Mertens, B.F. (1982) The Role of Iodine-Releasing Silicone Implants in Prevention of Spherical Contractures in Mice. *Plastic & Reconstructive Surgery* 69 (6): 956 – 959.
- Caufield, P.W. and Wannemuehler, Y.M. (1982) In vitro susceptibility of streptococcus mutans 6715 to iodine and sodium fluoride, single and in combination, at various pH values. *Antimicrob. Agents Chemother.* 22 (1): 115-9.
- Conn, H. and Langer, R. (1981) Iodine disinfection of hydrophilic contact lenses. *Ann. Ophthalmol.* 13 (3): 361-4.
- Gordon, J. (1993) Opening address, Closing remarks, and articles therein – Second Asian Pacific Congress on Antisepsis (Hong Kong) *in* *Postgrad Med J* 69 (suppl. 3), S1 – S134.
- Gristina, A.G. (1987) Biomaterial-Centered Infection: Microbial Adhesion Versus Tissue Integration. *Science* 237: 1588 – 1595.

- 5 Gupta, K., Scholes, D. and Stamm, W.E. (1999) Increasing Prevalence of Antimicrobial  
Resistance Among Uropathogens Causing Acute Uncomplicated Cystitis in Women.  
10 JAMA 281 (8): 736-738.
- Houang, E.T., Gilmore, O.J., Reid, C. and Shaw, E.J. (1976) Absence of bacterial  
5 resistance to povidone iodine. J. Clin. Pathol. 29 (8): 752-5.
- 15 Jansen, B. et al. (1992) In-vitro efficacy of a central venous catheter complexed with  
iodine to prevent bacterial colonization. J. Antimicrobial Chemotherapy 30: 135-139.
- 20 Kristinsson, K.G. et al. (1991) Antimicrobial activity of polymers coated with iodine-  
complexed polyvinylpyrrolidone. J. Biomaterials Applications 5: 173-184.
- 10 LeVeen, H.H. et al. (1993) The mythology of povidone-iodine and the development of  
25 self-sterilizing plastics. Gynecology & Obstetrics 176: 183-190.
- MacLellan, D.G. (1997) Foreword; Ermini, M. (1997) Current Povidone-Iodine  
Research: A Summary of the Papers Presented; see also articles therein - Third Asian  
30 Pacific Congress on Antisepsis (Sidney) in Dermatology 195 (suppl. 2), S1 - S120 (and  
15 abstracts S121 - S159).
- 35 Morain, W.D. and Vistnes, L.M. (1977) Iodinated Silicone - An Antibacterial Alloplastic  
Material. Plastic & Reconstructive Surgery 59 (2): 216 - 22.
- Rodeheaver, G., Turnbull, V., Edgerton, M.T., Kurtz, L. and Edlich, R.F. (1976)  
40 Pharmacokinetics of a new skin wound cleanser. Amer. J. Surg. 132 (1): 67-74.
- 20 Shikani, A.H. et al. (1996) Polymer-iodine Inactivation of the Human Immunodeficiency  
Virus. J. Amer. College of Surgeons 183: 195-200.
- 45 Tyagi, M. and Singh, H. (1997) Preparation and antibacterial evaluation of urinary  
balloon catheter. Biomedical Sciences Instrumentation 33: 240-45.

5 Zhang, X., Whitbourne, R. and Richmond, R.D. (1997) Antiinfective Coatings for  
Indwelling Medical Devices. Medical Plastics and Biomaterials, November/December  
10 Issue, pp. 16 – 24.

The disclosure of these and other references listed in the specification are hereby  
5 incorporated herein by reference in their entireties.

### BACKGROUND OF THE INVENTION

20 Introduction of medical devices implanted into the body can lead to serious  
nosocomial infections. Implanted medical devices (e.g., venous and arterial catheters,  
10 neurological prostheses, wound drains, urinary "Foley" catheters, peritoneal catheters,  
25 and other luminal indwelling devices), while sterilized and carefully packaged to guard  
against introduction of pathogens during implantation, pose a risk during insertion, and  
subsequently. During insertion, bacteria can be picked up from the skin and carried into  
30 the insertion site, where bacterial colonization may ensue. In the case of urinary and  
15 venous catheters, especially those used long-term, there is a significant threat of  
35 microbial growth along the exterior surface of the catheter. This can lead to chronic  
urinary tract infections (CUTI), or septicemia in the case of venous and arterial catheters,  
thrombotic emboli caused with infections introduced by the catheter, and other life-  
40 threatening complications, especially among the elderly. Methods aimed at  
20 circumventing this problem have included irrigating the implant site with antibiotic,  
applying various antibiotic ointments or antibiotic-impregnated sponges near the exterior  
45 opening by which infection most likely occurs, impregnating the polymer base coating  
the implant device with antibiotics or silver, either as a heavy metal or in combination  
50 with antibiotics, or treatment of patients systemically with antibiotics. Despite the

5 foregoing attempts at preventing infections associated with the implantation of catheters  
and lumenal indwelling devices in various body cavities, these methods of preventing  
10 and treating infections have not proven satisfactory.

For example, the long-term use, and misuse, of antibiotics often results in the  
5 selection of antibiotic-resistant strains. Hence, in general, systemic antibiotic therapy is  
15 ill advised and ineffective in warding off CUTI, for example. The secondary side effects  
of systemic antibiotic treatments can also pose a serious risk to many patients.

20 Furthermore, in many implant sites, the formation of fibrous tissue around the implant  
site reduces the supply of blood to the implant cavity, thereby precluding systemic  
10 antibiotic treatment of the critical space between the implant and capsular endothelial  
25 wall. In the case of a urinary catheter (*e.g.*, Foley catheter), antibiotics injected as a  
coating in the urinary canal may be washed out during drainage through leakage of some  
30 urine along the urinary tract outside the catheter, or resorbed before they can achieve  
sufficient levels to effectively kill bacteria growing within localized regions of the  
15 urinary tract.

35 It can be appreciated from the foregoing problems that there is a pressing need for  
the development of better methods of preventing and treating infections caused with  
catheter insertions into body cavities, particularly for the development of methods and  
40 devices which circumvent the problem of selecting out antibiotic-resistant organisms.

20 The problem is particularly acute, since it is known that when catheters and other  
indwelling lumenal devices are inserted into body cavities such as the urinary tract,  
45 venous or arterial vessels, a biofilm forms rapidly on the walls of the implant device.  
Bacteria then propagate free from attack by the body's own phagocytic defense system  
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and also free from systemic antibiotic treatments (Gristina, A.G., *Science* 237: 1588-1595 (1987); Zhang, X. et al., *Medical Plastics and Biomaterials*, Nov. 1997, pp. 16-24).

Free elemental iodine is attractive as an anti-infective agent. There are no known organisms which have developed resistance against its oxidizing activity in attacking critical sulfhydryl groups and other functional groups in proteins essential for bacterial survival (Second Asian Pacific Congress on Antisepsis *in Postgrad. Med. J.* 69 (suppl. 3), 1993: S1-S134; Third Asian Pacific Congress on Antisepsis *in Dermatology* 195 (suppl. 2), 1997: S1-S120 ). A few parts per million (ppm) in solution is sufficient to kill bacteria and viruses (LeVeen et al. (1993) *Gynecology & Obstetrics* 176: 183-190; Barabas, E.S. and Brittain, H.G. (1998) *in Analytical Profiles of Drug Substances and Excipients* (ed., Brittain, H.G.) Vol. 25, AP, San Diego, pp. 341-462). On the other hand, because of its high degree of diffusion through water, air, and lipids, and its reactivity as an oxidizing agent, elemental iodine is difficult to handle in a clinical setting.

Methods of stabilizing iodine in solution illustrated by the formulation, Povidone-iodine, for example, are well-known to those in the art. This formulation has been tried without satisfactory success in conferring to catheters anti-infective properties. Povidone-iodine washes free of devices as a coating and is consequently present an insufficient duration to significantly reduce the incidence of infections brought on following implantation, particularly in complex biological media. Jansen et al. (*J. Antimicrobial Chemotherapy* 30: 135-139 (1992)), and Kristinsson et al. (*J. Biomaterials Applications* 5: 173-184 (1991)), sought to confer to catheters anti-infective activity by pre-loading the lumen with iodine complexed with polyvinylpyrrolidone (PVP). While they were able to demonstrate weak anti-infective activity in aqueous buffered solutions,

5 this strategy proved unsatisfactory in complex media. Jansen reported that the activity  
conferred by this technique lasted for less than 3 hours in serum. Indeed, Jansen sought  
10 to pre-load PVP-coated catheters with Lugol's solution, a concentrated mixture of  
inorganic iodine and iodide, in an attempt to enhance the anti-infective activity of the  
5 iodine transferred to the catheter lumen. As noted below, and in example 8 illustrating  
15 the invention described herein, the use of iodophor complexing agents such as PVP,  
designed to sequester elemental iodine, works against, rather than promotes, conference  
20 of anti-infective activity to catheters. This can be appreciated since iodophors, in binding  
iodine, compete for iodine, decreasing its rate of egress across the polymer base of the  
10 catheter, thus ameliorating the effectiveness of iodine in conferring to catheters anti-  
25 infective activity.

Povidone-iodine, as it is commercially formulated with a total iodine content of  
30 10,000 ppm, also introduces a high iodine exposure level to the patient, of which only  
about 1 ppm is free iodine, the form necessary to effect microbial killing. PVP, the  
15 binding agent used in trapping iodine in aqueous solutions in a bound form, is also  
35 problematic in retarding wound-healing (LeVeen et al. (1993) Gynecology & Obstetrics  
176: 183-190). The short-lived retention of Povidone-iodine coatings on implant  
40 devices, the fact that binding agents such as PVP aggravate wound-healing, and the fact  
that the free form of iodine in Povidone-iodine at 1 ppm is below the essential ~ 2 ppm  
20 level of free iodine required for efficient microbial killing, points out the need for a better  
method of presenting iodine as an anti-infective agent to catheters and other indwelling  
45 implant devices (e.g., wound drains).

Morain and Vistnes (Plastic & Reconstructive Surgery 59: 216-222 (1977))  
50 sought to impregnate silicone discs with elemental iodine by soaking discs in 95%

5 ethanolic solutions in which crystalline iodine had been dissolved and then tested the  
discs for anti-infective activity. While they were able to demonstrate the release of anti-  
10 infective activity in their iodine-impregnated disc samples, they concluded that the use of  
iodine was "contraindicated" because of concern that it would add to the vinyl group of  
5 polymethylvinylsiloxane in the formulations they used, potentially altering "the  
15 substance sufficiently that an entirely new set of physiochemical properties might result."  
It is also apparent that the method of impregnating an implant using crystalline iodine  
and an alcoholic solution is impractical in a clinical setting. Iodine crystals in  
20 combination with alcohol can cause severe chemical burns if put into direct contact with  
tissues, it is difficult to control dosing of crystalline iodine in a reliable fashion, and it is  
10 messy working with mixtures of crystalline iodine and alcohol. Thus, the practical  
25 obstacles of preparing impregnated anti-infective implants using this technology pose  
serious logistical problems in the handling and release of iodine.

30 Birnbaum et al. (Plastic & Reconstructive Surgery 69: 956-959 (1982)) sought to  
15 confer to silicone breast implants anti-infective activity by injecting Povidone-iodine  
solutions into the internal cavity of the implants in studying prevention of spherical  
35 contractures believed to be caused by inflammation, but found fibrosis, collagen  
deposition, and inflammation comparable to that of control animals implanted with  
40 silicone implants lacking anti-infective activity. Birnbaum et al. taught that in their  
20 formulation, "the effects of iodine are limited to a prescribed period of time, following  
which all inhibitory activity is lost." They concluded that "...Bacteria arriving  
45 subsequent to this period of activity would not be inhibited. Fibrosis and late scar  
contracture might then ensue...", thus teaching away from the use of delivering free  
50 iodine into silicone polymer implants.

5 LeVeen and LeVeen (US Pat. No. 5156164) claimed to have conferred  
bactericidal activity to a contraceptive sponge by impregnating the polyurethane polymer  
base comprising the sponge with an aqueous solution of free iodine made up in Lugol's  
10 solution. More recently, Shikani and Domb (US Pat. No. 5695458; 5762638) described  
5 the fabrication of iodine-impregnated polymer coatings of varying thickness prepared by  
dissolving elemental iodine into organic solvents which also contained organic polymers  
which were then layered and coated by dipping and drying steps over medical devices  
including blood handling collection bags, tubes, catheters, and the like. This technology  
20 involves multiple layering of iodine-impregnated polymers, the spacing of additional  
10 layers of polymer lacking iodine dissolved in the organic solvents, and varying such  
25 steps aimed at retarding and managing the egress rates of free iodine from the polymer  
base to provide for a controlled anti-infective activity. In a similar fashion, Tyagi and  
Singh (Biomedical Sciences Instrumentation 33: 240-45 (1997)) sought to confer to latex  
30 Foley urinary balloon catheters anti-infective activity by dipping the outer external  
15 surfaces of the latex balloon in toluene solutions comprising a mixture of elemental  
iodine and latex and then drying and storing catheters treated in this manner at low  
35 temperature in polythene bags prior to use, however. Neither the polyurethane nor latex  
methods are amenable to on-site delivery of anti-infective activity to an existing catheter  
40 or implant device at the bedside, or in the surgical suite. The use of organic solvents,  
20 drying times, and multiple dipping steps make these methods impractical in a clinical  
setting for conferring anti-infective activity to the implant device.

The latter techniques of entrapping elemental iodine within a polymer base as  
taught by LeVeen and LeVeen, Shikani and Domb, and Tyagi and Singh, rely, in general,  
50 on starting with free elemental iodine dissolved within a solvent system, and trapping it

5 within a polymer base, a process wrought with technical difficulties. The layering and  
drying steps used in the art taught by Shikani and Domb, and Tyagi and Singh,  
10 moreover, is costly and time-consuming. In addition, none of the methods starting with  
free elemental iodine address the problem of how to ensure a long shelf-life for iodine  
5 entrapped within the polymer base of the implant device. Once the device is fabricated  
and loaded with iodine, it can be appreciated by those knowledgeable in the art that  
15 iodine will begin to diffuse into the air because of the inherent chemical properties of  
iodine to disperse free of its initial site of deposition. Furthermore, the high degree of  
20 reactivity of free iodine is a drawback to these methods. It can be anticipated, for  
example, that iodine will react and become depleted from the device in encountering  
25 varying reducing compounds coming into contact with the device. Such compounds  
capable of depleting the iodine entrapped within the device may be in the form of gases,  
liquids, or solids including the wrapping materials in which the devices are stored. In  
30 addition to these limitations, in the art taught by Shikani and Domb, and Tyagi and  
Singh, the layering of varying polymer layers atop one another using organic solvents in  
35 which iodine is dissolved is limited to polymers which are compatible with one another  
in forming strong and uniform adhesive bonds and which will not swell or alter shape  
when wetted and presented to a biological site of treatment. This is contrary to the  
40 properties of many medical grade polymers used in medical devices that have a tendency  
to swell and distort in shape once placed within the body. Polymer swelling and  
45 distortion is unacceptable in the art taught by Shikani and Domb, since the latter  
phenomenon results in rupturing of the adhesive bonds between the iodine-coated layers  
of the implant device and loss of control in the release rates of free iodine egressing from  
50 the device.

Therefore, there remains a need in the art to mitigate the risk of infection from such medical devices.

## SUMMARY

The invention is directed to methods of providing and/or maintaining anti-infective activity to a medical device generally comprising exposing the medical device to an anti-infective oxidant and transferring the anti-infective oxidant into a wall of the medical device. The phrase "anti-infective activity" should be understood to mean either activity against infection or maintenance of a dis-infected state. One embodiment comprises exposing a medical device which is at least in part within a patient to the anti-infective oxidant. The phrase "within a patient" should be understood to mean a device which is disposed in a natural body lumen such as an oral or vaginal cavity, as well as a device disposed in the body via a surgical incision therein. Additionally, the term "patient" should be understood to include humans, as well as animals. Another embodiment comprises exposing a medical device to an aqueous solution which produces the anti-infective oxidant and transferring a sufficient amount of the anti-infective oxidant into the medical device wall to provide the medical device with anti-infective activity. The invention also provides an anti-infective medical device having a wall, said device being designed for introduction into the body of a patient, at least a portion of said device, and said wall, being in contact with an anti-infective oxidant.

Another aspect of the invention is directed to an oxidant-releasing member which has the anti-infective oxidant releasably contained therein and which is configured to be disposed adjacent to the medical device. Presently preferred medical devices useful in the method of the invention include catheters such as venous, arterial, and urinary catheters, generally comprising an elongated catheter shaft having a lumen extending

5 therein, and optionally having a balloon on the shaft in fluid communication with the catheter lumen.

10 The medical device can be exposed to the anti-infective oxidant by a variety of suitable methods. In one embodiment, the medical device is exposed to a formulation  
5 which generates the anti-infective oxidant. For example, the formulation can be delivered into a lumen of the device or into the interior of a balloon of the device, or the  
15 device can be at least in part submerged within the formulation. The formulation can be delivered into the lumen of the medical device using a tubular delivery member inserted  
20 into the medical device lumen or by attaching a source of the formulation to a port, such as the port in a side arm adapter, on the proximal end of the medical device. A viscosity-  
25 increasing compound such as a hydrogel, such as a carbopol, may be added to the oxidant-generating formulation to inhibit the expulsion of the formulation from the medical device lumen. In an alternative embodiment, the oxidant is transferred into a  
30 wall of the medical device from an oxidant-releasing member having the anti-infective oxidant releasably contained therein. The oxidant-releasing member is preferably  
35 formed of a polymer, and has a dispersion of the oxidant within the polymer. The oxidant-releasing member may be provided with the oxidant by a variety of suitable methods. For example, the oxidant-releasing member can be exposed to a formulation  
40 which generates the oxidant, so that the oxidant diffuses into the polymeric wall of the oxidant-releasing member. Alternatively, the oxidant-releasing member can be formed  
20 of a polymer having a solid-phase dispersion of oxidant-producing compounds therein which require a component such as water to be exposed to the oxidant-producing  
45 compounds to produce the oxidant when desired. A presently preferred material of the oxidant-releasing member is a hydrophobic polymer, such as a polyethylene, however, a  
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5 variety of suitable materials may be used depending on the oxidant type and  
concentration, and the medical device used. In a presently preferred embodiment, the  
10 oxidant-releasing member has an elongated body configured to be slidably inserted into a  
lumen of the medical device. However, the oxidant-releasing member may,  
5 alternatively, be configured to be disposed around at least a section of the medical  
15 device. The oxidant-releasing member may have a variety of suitable shapes including  
rods, tubes, or the like. In one embodiment, the oxidant-releasing member is a rod  
20 having at least one channel on an outer surface of the rod configured to allow fluid flow  
therein. In certain types of catheters where liquids cannot be safely injected directly into  
10 the luminal space, as in the case of certain venous or arterial catheters, the insertion of an  
25 oxidant-releasing member into the lumen of the catheter is the preferred method of  
exposing the medical device to the anti-infective oxidant. Alternatively, in catheters  
such as urinary catheters, the oxidant-generating formulations can typically be introduced  
30 into the catheter lumen.

15 After a short interval following exposure of the medical device to the anti-  
35 infective oxidant, as for example by introduction of the oxidant-generating formulation  
or oxidant-loaded rod into the luminal space of the device, sufficient to allow for transfer  
of the oxidant to the walls of the medical device, the oxidant-generating formulation or  
40 the rod can be removed, having deposited its intended load of anti-infective oxidant to  
the medical device. Thereafter, oxidant diffuses to the external walls of the medical  
20 device, conferring to it anti-infective activity. In a presently preferred embodiment, a  
single exposure to the anti-infective oxidant is required to provide the medical device  
45 with anti-infective activity for a given period of time, unlike prior art methods requiring  
multiple exposures. The medical device is exposed to the anti-infective oxidant typically  
50



5 for about 1 to about 30 minutes to transfer the oxidant to the medical device. The  
oxidant-generating formulation introduced into the medical device lumen or exposed to  
10 the oxidant-releasing member produces sufficient amounts of anti-infective oxidant to  
transfer about 2 to about 300 ppm, preferably about 2 to about 10 ppm of anti-infective  
5 oxidant into a wall of the medical device. The oxidant-generating formulation produces  
15 about 0.1 to about 300 ppm, preferably about 2 to about 10 ppm of anti-infective oxidant,  
depending on the oxidant used.

20 The anti-infective oxidant has microbicidal and virucidal activity due to its  
oxidative activity. Suitable anti-infective oxidants include elemental iodine (also called  
10 free iodine), hypohalites, haloamines, thiocyanogen, and hypothiocyanite. The anti-  
25 infective oxidants are produced by the oxidant-generating formulations by the oxidation,  
reduction, or hydrolysis of the oxidant-producing component.

30 In the case of elemental iodine, the oxidant-producing component in the oxidant-  
generating formulation is an iodine-containing salt which is oxidized or reduced, to  
15 produce elemental iodine. A source of protons is required to drive the oxidation or  
35 reduction of iodine-containing salt to elemental iodine. Iodine-containing salts suitable  
for use in the invention include iodides, which oxidize to elemental iodine, and iodates,  
which reduce to elemental iodine. Suitable iodides include any of the iodides of alkali  
40 and alkaline earth metals, such as sodium iodide, potassium iodide, calcium iodide, and  
barium iodide. Suitable iodates include iodates of alkali metals such as sodium iodate,  
20 potassium iodate, and iodine pentoxide. In the case of iodates, the iodate may act as both  
45 a source of iodide and an oxidizing agent which oxidizes iodide to elemental iodine.

50 This invention takes advantage of the chemical properties of iodine to diffuse  
freely through hydrophobic and hydrophilic phases and exploits this property of iodine in

5 moving it to desired sites for egress to the exterior surfaces of lumenal implant devices,  
where anti-infective activity is needed to prophylactically prevent, and to treat infections  
10 linked with implantation of the lumenal device. Moreover, oxidant-generating  
formulations used in the method of the invention provide for rapid formation of  
5 elemental iodine. The oxidant-generating formulations preferably include a suitable  
15 proton source, along with precursors required for the generation of elemental iodine, to  
ensure rapid formation of elemental iodine and, consequently, the rapid uptake of  
20 elemental iodine by the medical device or the oxidant-releasing member. The oxidant-  
generating formulation produces at least about 0.1 ppm of elemental iodine, and  
10 preferably about 2 ppm to about 300 ppm of elemental iodine, and most preferably about  
25 5 ppm to about 10 ppm elemental iodine per treatment, so that about 2 ppm to about 300  
ppm of the elemental iodine per treatment, or about 2 micrograms of elemental iodine per  
30 day, preferably not more than 1500 micrograms of elemental iodine per day diffuses  
from the medical device to the patient to provide anti-infective activity to the medical  
15 device.

35 In the case of hypohalite as the anti-infective oxidant, the oxidant-producing  
component comprises a halide-containing compound oxidized by an oxidizing agent to  
produce the hypohalite. Similarly, a thiocyanogen or hypothiocyanite anti-infective  
40 oxidant can be produced by the oxidation of a thiocyanate.

20 A variety of suitable oxidizing agents may be used to oxidize the oxidant-  
producing component, including iodine oxide salts, peracids, and substrate  
45 oxidoreductases. Suitable iodine oxide salts include alkali or alkaline earth metal iodates  
such as potassium iodate, sodium iodate or calcium iodates, and iodine pentoxide.  
50 Suitable peracids include perborates and organic peroxyacids.

5 A variety of suitable reducing agents may be used to reduce the oxidant-producing component. For example, where the oxidant-producing component is an  
10 iodate, any iodate oxidizable substrate such as ascorbate, thiols, and organic aldehydes may provide the reducing equivalents to reduce iodate to elemental iodine.

15 A variety of suitable proton-producing agents may be used including an anhydride which, upon exposure to water, spontaneously hydrolyzes to an acidic product or an enzyme acting on a substrate which catalyzes formation of an acid product. In a  
20 presently preferred embodiment, the proton-producing agent is selected from the group consisting of iodine pentoxide, an organic or inorganic acid, and enzyme oxidase such as  
10 glucose oxidase, and an anhydride such as succinic anhydride, maleic anhydride, succinyl maleic anhydride, and acetic anhydride.

Although discussed primarily in terms of an elemental iodine anti-infective  
30 oxidant, it should be understood that the various embodiments discussed herein may involve the use of alternative anti-infective oxidants. Thus, for example, alternative  
15 oxidants which can be caused to form on demand from precursor reactants include hypohalites such as hypochlorite ( $\text{OCl}^-$ ), hypoiodite ( $\text{OI}^-$ ), and hypobromite ( $\text{OBr}^-$ );  
35 haloamines including chloramines, iodamines, and bromamines which are the oxidizing products formed through reaction of hypohalites with primary and secondary amines  
40 such as taurine chloramine formed by introduction of taurine to hypochlorite; thiocyanogen ( $(\text{SCN})_2$ ); and hypothiocyanite ( $\text{OSCN}^-$ ).  
20

45 The method of the invention provides improved anti-infective activity to medical devices, due to the anti-infective oxidant which is formed in solution rapidly and in sufficient quantity to deposit controllable, desired concentrations of the oxidant onto the  
50 luminal walls of the medical device, or loading rod, whence transfer across the polymer

5 wall ensues. The ability to exploit chemical formation of free iodine *de novo*, and  
positioning and transfer of elemental iodine using this chemistry within the luminal  
10 cavity at a specific site for the treatment and prevention of infections, is of great  
advantage, because it allows this technology to be used on existing luminal implant  
15 devices such as urinary, venous and arterial catheters, wound drains, and other  
indwelling luminal devices, without the expense and retooling necessary in  
manufacturing anti-infective activity into a device as it is produced by the manufacturer.  
20 Furthermore, this technology allows clinicians and users of this art to tailor the frequency  
of treatment to the needs of the patient in preventing, or treating, an infection, and, thus,  
10 this technology offers great flexibility in its application in the clinical setting. These and  
25 other advantages of the invention will become more apparent from the following detailed  
description and accompanying figures.

30 The invention further provides a method of dis-infecting a medical device for  
administration to the body of a patient, said device having a wall. Finally, the invention  
15 provides a method of controlling microbial growth on a surface of a medical device  
35 designed for administration to the body of a patient, said device having a wall. The latter  
two methods comprise exposing the medical device in its administered state to an anti-  
40 infective oxidant and bringing the oxidant in contact with a wall of the device. Thus, the  
use of an anti-infective oxidant in the dis-infection of a medical device is an additional  
20 embodiment of the invention, as is the administration of a medical device according to  
45 the above description to a patient.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 shows the effect of varying the pH of buffered citrate solutions (50 mM) on the rate of free elemental iodine formation using potassium iodide and sodium iodate as precursors. The optimal pH for iodine formation is approximately 4.5.

Fig. 2 shows the recovery of iodine released from polyvinylchloride (PVC) tubing pre-loaded with varying concentrations of iodine formed using the method of providing anti-infective activity of the invention, i.e., in-situ chemical anti-infective loading technology (herein after "ICAT") for iodine generating formulations versus immersion times of the catheter in oxidant generating formulations (i.e., "ICAT fluid").

Five cm lengths of PVC tubing (outer diameter, 5.5 mm; inner diameter, 3.0 mm) were pre-loaded with iodine generating formulations made up of parts A and B in which the final concentration of inorganic sodium iodide ranged from 2.5 (solid circles), to 12.5 mM (solid squares) to 50 mM ("x" symbols), respectively. The final concentration of Carbopol C971 PNF was made up as 0.25%, and sodium iodate was held constant at 12.5 mM. The pH of the iodine generating formulation was 4.6.

Fig. 3 shows the corresponding uptake of free iodine from the internal lumen after loading of ICAT into the same PVC tubing as in Fig. 2 using a final concentration of sodium iodide of 25 mM with sodium iodate held constant at 12.5 mM, Carbopol C971 PNF held at 0.25%, and the final pH set at 4.6. The concentrations shown in Fig. 3 represent 1/100<sup>th</sup> of the actual concentration of free iodine present in the internal lumen of the catheter at the intervals indicated in Fig. 3.

Fig. 4 demonstrates the kinetic transfer of free elemental iodine from a prefabricated hydrophobic polyethylene(PE) tab (dimensions, 8.5 x 0.5 x 0.05 cm [length x width x thickness]), loaded with free elemental iodine using ICAT technology, to free

solution (10 ml of 10 mM KI). Each point on the graph reflects the level of free iodine recovered in the immersion fluid in which the PE tab was placed.

Fig. 5 shows the release rates of free iodine egressing from the exterior wall of silicone catheters pre-loaded for 20 minutes with ICAT iodine generating formulation.

The upper tracing shows the results of iodine egress from the external walls of a catheter with a diameter twice that of the lower tracing (total ICAT fluid volumes pre-loaded into the catheters are indicated to the right of each tracing).

Fig. 6 shows the release of free iodine from the exterior walls of silicone catheters submerged in 10 ml potassium iodide using varying concentrations of sodium iodide in the ICAT formulation delivered to the inner lumen from a low concentration of 1.6 mM to a high of 25 mM, as indicated, as a function of immersion interval. The concentration of sodium iodate and Carbopol C971 PNF was kept constant at 12.5 mM and 0.25%, respectively.

Fig. 7 shows the effect of pre-loading interval (residence time of ICAT within the lumen) on egress of free iodine from silicone catheters. In these experiments, 5 cm segments of silicone catheters (lumen volume, 0.2 ml) were loaded with ICAT iodine generating formulation with the final sodium iodide concentration set at 25 mM, sodium iodate at 12.5 mM, and Carbopol C971 PNF at 0.25%, for the intervals noted. Thereafter, the ICAT solutions were flushed free of the catheter with distilled water, the catheters were recapped with glass rods, then immersed in 10 ml of 10 mM potassium iodide and tracked for release of free iodine egressing from the walls of the catheter into the external fluid at 4 hours after immersion.

Fig. 8 shows the egress of free iodine from the walls of silicone catheters submerged in 10 ml 10 mM potassium iodide following ICAT treatment with iodine

5 generating formulations, but with replacement of Carbopol in Part B of the formulations  
with 25 mM potassium citrate buffer adjusted to a final pH of 4.2. Potassium iodide in  
10 the iodine generating formulation was varied from 6.3 to 50 mM. The concentration of  
sodium iodate was kept constant at 12.5 mM. Also shown in Fig. 8 is the corresponding  
5 egress rate of free iodine versus submersion interval for a silicone catheter loaded with  
15 10% Povidone-Iodine(PVP-I) substituted in place of the ICAT iodine generating  
formulation.

20 Fig. 9 shows the release of free iodine from the external walls of a McComb  
neonatal catheter as affected by varying potassium iodide concentrations formulated in  
10 ICAT iodine generating solutions to which the catheter was initially exposed. To test the  
25 efficacy of transiently loading iodine into the polymer base of the McComb catheter  
(Model NNCR3, Phoenix Biomedical Corp, Valley Forge, PA) using ICAT, solutions  
were made up at varying concentrations (final concentration after mixing parts A & B  
30 together) of potassium iodide as indicated in Fig. 9 while holding the final concentration  
15 of sodium iodate and potassium citrate at 12.5 and 25 mM, respectively. The solutions  
35 were buffered to pH 4.2. The catheter was submerged in ICAT solutions of varying  
potassium iodide concentration and incubated for 20 minutes. Thereafter, the catheter  
was rinsed in distilled water and transferred to 10 ml solutions of 10 mM potassium  
40 iodide placed inside a capped polycarbonate tube. At varying intervals the egress of pre-  
20 loaded iodine taken up by the catheter was measured. In these measurements the inner  
reservoir of the catheter was capped with a nylon plug so that only the egress of iodine  
45 from the exterior side of the catheter was tracked.

Fig. 10 shows the egress rate (and "hook" effect – see example 9) of free iodine  
50 from the external walls of McComb catheters pretreated with ICAT iodine generating

formulations made up at varying concentrations of potassium iodide. The maximum recovery of iodine peaked around 30 mM potassium iodide yielding about 30 ppm free iodine (in a 10 ml fluid volume) coming back off of the polymer base approximately 40 minutes after rinsing the catheter free of ICAT iodine generating solution.

Fig. 11 is a schematic illustrating loading of ICAT iodine generating formulations into the inflatable balloon of a Foley urinary catheter by placing ICAT solution contained in a Luer-lock syringe (not shown) into the entry port of the valve at the proximal end of the catheter. Compression of the syringe expresses ICAT solution through the internal cannular lumen built into the wall of the Foley catheter which communicates with the balloon, and allows ICAT solution to enter and inflate the balloon. The central lumen allows for urine to pass freely from the bladder via the bladder drain through the catheter and into a urine waste container (not shown). The light arrows perpendicular to the plane of the catheter walls depict egress of free iodine across the catheter wall and to the external surface of the catheter, conferring anti-infective activity to the ICAT-loaded catheter.

Fig. 11a illustrates a transverse cross-sectional view of the catheter shown in Fig. 11, taken along lines 11a-11a.

Fig. 11b illustrates a transverse cross-sectional view of a catheter having an oxidant-releasing member in a lumen of the catheter.

Fig. 12 is an elevational view of tubular delivery member which embodies features of the invention.

Fig. 12a illustrates a transverse cross-sectional view of the tubular delivery member shown in Fig. 12, taken along lines 12a-12a.



Fig. 13 is an elevational view of an oxidant-releasing member which embodies features of the invention.

Fig. 13a illustrates a transverse cross-sectional view of the oxidant-releasing member shown in Fig. 13, taken along lines 13a-13a.

Fig. 14 illustrates a transverse cross-sectional view of an alternative embodiment of the oxidant-releasing member, having grooves in an outer surface of the oxidant-releasing member.

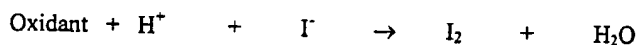
Fig. 15 shows the kinetic egress of nascent iodine from the external balloon walls of Foley catheters made of silicone (dashed line) and latex (solid line) inflated with ICAT iodine generating solutions. The ICAT solutions were formulated at a fixed concentration of iodate (12.5 mM) and potassium citrate (25 mM), and potassium iodide was adjusted to either 30 mM (solid symbols), or 15 mM (open symbols). To initiate transfer of nascent iodine formed by ICAT to the Foley catheters, 5 ml of "Part A" ICAT (either 30 or 60 mM potassium iodide made up in distilled water, as indicated) was premixed with 5 ml of "Part B" ICAT (50 mM potassium citrate, pH 4.2, made up in 25 mM sodium iodate in distilled water). This mixture was immediately transferred to a 10 ml Luer lock syringe and injected through the Luer lock type connector or valve of the Foley catheter resulting in inflation of the catheter balloon. The inflated balloon was then submerged beneath 100 ml 10 mM potassium iodide within a glass jar in which a magnetic mixing bar was also included to facilitate uniform mixing and sampling of solution coming into contact with the external side of the balloon wall. Values shown represent recovered free iodine in the solution bathing the inflated balloon at the times indicated.

Fig. 16 shows the egress rates of elemental iodine from an ICAT-Loaded Balloon of a Latex Urinary Catheter versus Concentration of PVP contained within the ICAT formulation.

## DETAILED DESCRIPTION OF THE INVENTION

### 5 Overview of the Device and Formulation Chemistry

In a presently preferred embodiment, the anti-infective oxidant is elemental iodine. The *de novo* generation of free elemental iodine from precursor inorganic iodide provides the basis for producing free iodine on demand, as needed, in allowing for transient presentation and transfer of iodine to luminal catheter implant devices. Varying methods and formulations for its production have been described in prior art (US Pat. Nos. 4278548, 4312833, 4476108, 5232914, 5607681, 5648075, 5849241). These methods have in common the presentation of inorganic iodide, an oxidant (either enzymatic or inorganic), a proton source and water as a solvating agent in combination to effect formation of free elemental iodine through oxidation and conversion of iodide into iodine in accordance with the following general equation:



Depending upon the oxidant used, other byproducts of the reaction may arise (vis., gluconate in the case of glucose oxidase, wherein the proton generated in the formation of gluconic acid, and hydrogen peroxide formed with consumption of molecular oxygen, are converted to water concomitant with iodine formation). In the present invention, the precise method of forming free elemental iodine *de novo* starting with inorganic iodide is not critical as long as excess iodine is formed in solution rapidly

5 and in sufficient quantity to deposit onto the luminal walls of the implant device, or  
loading rod, whence transfer across the polymer wall ensues. The other key elements in  
10 the present invention involve devices for positioning of the chemistry within the implant  
device at appropriate sites required for conferring anti-infective activity to the implant  
15 device and exploitation of the properties of the luminal space in ensuring appropriate  
dispersion of free iodine to the desired sites of treatment.

The principle of transiently loading luminal implant devices with anti-infective  
20 free iodine exploits the propensity of free iodine to diffuse freely through hydrophilic and  
hydrophobic polymers, and thus to disperse to the exterior wall of the implant device  
10 where anti-infective activity is sought in prophylactically preventing the establishment of  
25 an infection between the exterior walls of the implant device, and the biofilm formed on  
the surface of the device. Similarly, where an infection has become established in an  
existing implant body cavity, free iodine can be delivered to the site using this  
30 technology through movement of iodine generated *de novo* across the walls of the  
15 implant device to the localized site of infection adjacent to the implant device. To  
35 achieve bacterial killing, the free iodine level egressing from the device should  
preferably attain a level of not less than 2 ppm nor exceed about 300 ppm within the  
40 body fluid to be treated. Levels in excess of 300 ppm are unnecessary and may lead to  
crystallization of free iodine from the body fluid, resulting in undesirable concentrations  
20 of iodine within the treatment site.

45 Methods of Dis-infecting a Medical Device or Controlling Microbial Growth on a  
Surface of a Medical Device in Use

The invention provides a method of dis-infecting a medical device designed for  
50 administration to the body of a patient, said device having a wall. The invention further

provides a method of controlling microbial growth on a surface of a medical device designed for administration to the body of a patient, said device having a wall. Both methods comprise exposing the medical device in its administered state to an anti-infective oxidant and bringing the oxidant in contact with a wall of the device.

5 Additionally, both methods may embody the specific features of claims 2 to 24, below.

Specifically, the methods of dis-infecting and/or controlling the surface microbial growth of a medical device in use may comprise a medical device which has a lumen, the defining wall of which may be exposed to an anti-infective oxidant. Further, the device in question may comprise a catheter with a lumen-defining shaft and a balloon whose interior is in fluid communication with the shaft lumen. A removable oxidant-generating formulation may be delivered to the lumen via a tubular delivery member, which may be inserted into the lumen of the medical device. The method may include as a last step the removal of the oxidant from the lumen of the medical device. Addition of a viscosity-increasing hydrogel to the formulation will inhibit its expulsion therefrom.

15 The anti-infective oxidant in contact with the medical device according to the methods in question may comprise elemental iodine, which may be delivered to the lumen of the medical device in the form of an elemental iodine-generating formulation produced by combining an iodide-comprising solution with an iodate-comprising solution. The oxidant-generating formulation may likewise produce elemental iodine and may optionally include an enzyme such as oxidoreductase. The medical device in use may be exposed to a fluid containing a proton-generating substrate or an iodide oxidizing agent. The oxidant-generating formulation may comprise an iodate, which may be reduced to elemental iodine. An oxidant-releasing member, which may constitute a slidably insertable elongated body, such as a rod, can be exposed to such an

oxidant-generating formulation, or an elemental iodine-generating formulation comprising iodide, iodate, and a proton source, and inserted into the lumen of the medical device. The insert member may be positioned in the lumen such that the amount of oxidant-generating formulation delivered into the lumen is reduced. The member may contain an anti-infective oxidant, for example, elemental iodine, releasably within. The elongated body of the anti-infective oxidant-releasing member may be formed of a polymeric material that allows diffusion of elemental iodine within. If the member is a rod, it may be solid and may further include at least one exterior channel for fluid flow. The outer diameter of the elongated body may be about 90% to about 5% , and preferably about 20% less, than an inner diameter of the lumen of the medical device.

About 2 ppm to about 300 ppm of the anti-infective oxidant, optionally constituting elemental iodide, may be transferred from an exterior surface of the medical device to the patient. The transfer of oxidant to a wall of the medical device may occur via diffusion, and may optionally take 1 to about 30 minutes. The binding of the anti-infective oxidant, including elemental iodine, within a wall of the medical device may be inhibited, for example, via provision of a device free of iodine binding agents. Likewise, provision of a formulation including an anti-infective oxidant binding agent inhibits transfer of the bound oxidant to a wall of the medical device. This binding agent may be any one of the following: silicone oil, mineral oil, cadexomers, and polyvinylpyrrolidone, and its presence may, in fact, increase the duration over which at least about 2 ppm of the anti-infective oxidant is transferred to a surface of the medical device. Optionally, the anti-infective oxidant may be elemental iodine, the binding agent polyvinylpyrrolidone, which may be about 1% to about 10% weight per unit volume of

the formulation, and the duration over which at least about 2 ppm of the elemental iodine is transferred to a surface of the medical device is increased.

The dis-infection of a medical device for administration to a patient may likewise be effected by exposing the medical device to an anti-infective oxidant-producing solution at least once, followed by transfer of oxidant to a wall of the device. In a particularly preferred embodiment, the solution may be aqueous, and the oxidant produced may be elemental iodine. The aqueous solution may produce at least 0.1 ppm of elemental iodine, optionally about 2 ppm to about 10 ppm of iodine. Preferably, about 2 ppm to about 300 ppm elemental iodine is transferred in use, and the total amount transferred per day should not exceed 1000 micrograms.

#### Delivery of Free Elemental Iodine Anti-Infective Activity to the Implant Device

For delivery and positioning of the chemistry within the lumenal space of the implant device, three general techniques have been developed. The first is to use a "blind" lumen (a dead-end lumen without communication to body fluids) or a balloon cannular entry port fabricated into the implant device as the means for delivery of free iodine to the implant device. An example of this type of delivery vehicle entails use of inflatable balloons built into catheters such as a Foley catheter for retention of the inserted device within the urethral canal and anchored by inflation of the balloon at the base of the bladder. In this design, a separate lumen is designed into the catheter leading to an inflatable balloon with a septum lock in which sterile water is ordinarily injected in expanding the balloon once it has been inserted with its tip and deflated balloon end penetrating into the bladder from the urethral canal. Such devices are common in catheter devices used to anchor, or secure, catheters against the walls of a vessel, and are familiar to those working in this art. In the present invention, the lumen used to inflate the

balloon, as well as the internal reservoir of the balloon, can be used as the site for delivering iodine-generating chemistry by substituting an appropriate iodine-generating formulation (see below) in place of sterile water as the inflating agent for the balloon.

The frequency of dosing and loading the catheter with anti-infective iodine can be made

as desired by replacing the fluid injected through the lumen to the balloon reservoir with fresh solutions of iodine-generating formulation. Iodine generated within this reservoir, and within the lumen leading to the balloon, disperses readily to the walls of the implant

device, and egresses to the external walls of the device, thus lending to the device anti-infective properties. A similar cannular loading port and balloon to allow for loading of

free iodine, generated *de novo* in the loading solution, can be built into a venous or arterial catheter to confer to the latter anti-infective activity. Fig. 11 illustrates a urinary

catheter 10 having a catheter shaft 11 with a proximal end 12, a distal end 13 and an inflatable balloon 14 on a distal section of the shaft. The balloon has an interior in fluid communication with inflation lumen 15 which extends within the catheter shaft 11. The

catheter shaft also has a central drain lumen 16 which extends from a port on the proximal end of the catheter to a port on the distal end of the catheter, which, in use, is typically connected to a waste container for body fluids. A valve or connector 18 is on the proximal end of the catheter, and the inflation lumen 15 is in communication with port 17 on the proximal end of the catheter at the valve 18. Fig. 11a illustrates a

transverse cross-sectional view of the catheter shown in Fig. 11, taken along lines 11a-11a. As discussed above, the oxidant-generating formulation is introduced into the inflation lumen 15, central lumen 16, or the interior of balloon 14. Fig. 11b illustrates an oxidant-releasing member 30 disposed within the central lumen 16 of the catheter 10 in

accordance with the method of the invention. The oxidant-releasing member could alternatively be introduced into the inflation lumen 15.

Where liquid formulation can be tolerated within the central lumen of the medical device, free iodine generated *de novo* can be delivered directly into the central lumen at a point distal from the proximal drain port as desired. In one embodiment, a tubular delivery member 20, as illustrated in Fig. 12, comprising a body 21 and a lumen 22 configured to deliver the fluid into the device lumen is used to deliver the formulation. Fig. 12a illustrates a transverse cross section of the tubular delivery member 20 shown in Fig. 12, taken along lines 12a-12a. The tubular delivery member 20 is preferably narrow bore, flexible tubing cut to the desired length, and fitted with a Luer lock over a syringe (not shown) loaded with the iodine-generating formulation. The tubing 20 is typically inserted into the lumen 16 of the catheter through the drain site of the catheter, so that the tubing slides as far as possible into the lumen, and allows for positioning of the end of the tubing used to deliver free iodine formed in the loading formulation at the point of application desired within the catheter. With expulsion of the syringe contents into the lumen, in a closed end lumen, fluid injected from the syringe flows backward from the dispensing tip toward the exit drain site, since this is the route of least resistance. Hence, free iodine can be delivered from the loading tip of the tubular delivery member 20 inserted into the catheter lumen 16 back towards the drain site over any region of the catheter as desired. Following a brief interval of no more than a few seconds after dispersion of the free iodine-generating solution, the tubular delivery member 20 may be withdrawn, leaving the loaded formulation to flush free of the lumen catheter through natural drainage of the lumen with body fluids. Alternatively, the formulation can be flushed or withdrawn by reinsertion of the tubular delivery member 20 back into the



luminal cavity of the catheter, and by injecting a wash solution of isotonic saline, or drawing back on the syringe plunger, depending upon the option chosen, following transfer of free iodine formed in the chemical formulation to the walls of the catheter.

The third embodiment for loading free elemental iodine into an indwelling catheter, or luminal implant device, involves inserting an oxidant-releasing member containing the anti-infective oxidant into the catheter lumen. In a presently preferred embodiment, the oxidant-releasing member is a solid, flexible rod, fabricated to the length and diameter of the lumen device in which it is to be inserted, which is at least in part immersed into an iodine-generating formulation made up and activated to form free elemental iodine just before insertion of the rod into the device. Fig. 13 illustrates an oxidant-releasing member 30 which embodies features of the invention, having a body 31 configured to be slidably disposed in the medical device lumen. In the embodiments illustrated in Figs. 12 and 13, the delivery and releasing members 20/30 have tapered distal ends to facilitate insertion within the device lumen. However, a variety of suitable configurations may be used, including distal ends which are not tapered. Fig. 13a illustrates a transverse cross section of the oxidant-releasing member 30 shown in Fig. 13, taken along lines 13a-13a. Fig. 14 illustrates an alternative embodiment of the oxidant-releasing member in which grooves 32 are provided on an outer surface of the body 31. The grooves are typically longitudinally disposed along the axis of the body 31 to allow fluid to flow through the lumen insert, or drain from the insert, with the rod in place during transfer of iodine to the walls of the implant device. The rod can be fabricated to serve as a plug, fitting snugly against the inner walls of the luminal wall of the implant device during transfer of iodine anti-infective activity to the implant device. This third embodiment addresses transfer of anti-infective iodine activity to luminal

5 walls of implant devices such as venous or arterial catheters where direct injection of  
iodine-generating fluid formulations into blood is unacceptable because of pH  
10 incompatibilities, the possibility of adverse reactions of components of the iodine  
generating formulation with constituents in blood, or the possibility of thrombolytic  
15 reactions induced with delivery of the formulation fluid directly into the bloodstream.  
The solid rod serves as a solid-phase transporter of free iodine. In the case of a venous  
catheter, for example, the rod would displace blood from the catheter, yet upon removal,  
20 leave no residual fluid within the lumen space. Suitable materials for fabrication of the  
rod include, but are not restricted to, hydrophobic polymers such as polyethylene, Teflon,  
10 silicone, polystyrene, polypropylene, polyurethane, and/or polycarbonate. The critical  
25 feature is that the solid polymer is able to accept free iodine generated *de novo* from the  
iodine generating formulation in which the rod is immersed, and upon removal and  
insertion of the rod into the implant lumen, that free iodine taken up in the rod is then  
30 able to re-equilibrate and back-diffuse out of the rod and into the walls of the implant  
15 device whence anti-infective activity is conferred to the implant device.

35 While it should be appreciated that there is considerable latitude in the design of  
the rod insert with regard to its length and geometrical shape, preferably the rod insert  
should be of small enough diameter so that it slides smoothly through the lumen of the  
40 implant device without binding or grabbing too tightly against the walls of the inner  
20 luminal wall precluding its easy insertion to the full insertion length intended in its  
positioning within the lumen. This restriction also dictates that it have sufficient stiffness,  
45 yet flexibility, so that it can be pushed into the lumen without hanging up on the walls of  
the lumen. Alternatively, it is desirable that the reservoir for holding free iodine is of  
50 practical volume so as to allow for a significant transfer of iodine to the walls of the  
55

5 implant device. In a practical application, the rod should occupy not less than about 5%  
nor more than about 90% of the total volume of the lumen space when inserted, with the  
10 preferred diameter approximately 80% of the inner luminal wall diameter of the implant  
device. Furthermore, in the preferred embodiment, the ends of the rod should be rounded  
5 so as to allow it to slide freely along the inner luminal wall of the implant without  
15 binding or catching.

In the case of the tubular delivery member designed for insertion and loading *de*  
20 *nov*o generating iodine formulations directly into the central lumen of an implant device,  
the diameter of the loading lumen should most preferably be kept small relative to the  
10 diameter of the implant lumen to receive anti-infective iodine. In the loading cannula, its  
25 outer diameter should be not less than about 5% nor exceed by more than about 90% the  
diameter of the implant lumen, with the preferred diameter about 10% of the implant  
inner wall diameter. As in the case of the rod insert, the tubular delivery member should  
30 preferably have a rounded edge at its loading end to prevent binding and catching of the  
15 tubular delivery member on the inner luminal walls of the medical device as it is  
35 inserted, and similarly it needs to have a flexibility and stiffness suitable so that it allows  
for easy insertion and sliding of the loading tip to the desired site within the medical  
40 device.

#### Formulation Used for Generating *De Novo* Free Elemental Iodine Anti-Infective Activity

20 Although as noted in the overview there are several formulations for generating  
free elemental iodine, in the preferred embodiment sufficient inorganic iodide must be  
45 available, along with an oxidant and a proton source, to ensure production of free  
elemental iodine in excess of 300 ppm. In this manner, iodine generated *de novo* can be  
50 caused to quickly enter within the inner walls of the implant lumen, or onto the loading  
55

5 rod insert, thereby accelerating and improving the efficiency of transferring iodine to the  
implant device. In certain applications a hydrogel may be included in the formulation to  
10 increase the viscosity of the final formulation so that it does not readily flush out of the  
device with removal of the loading cannula used in depositing the formulation into the  
5 inner lumen of the indwelling device. While there are a variety of oxidants such as  
15 perborates, peroxy acids, enzyme oxidoreductases (vis., glucose oxidase, diamine  
oxidase, galactose oxidase, etc.) in combination with peroxidases (vis., horse radish  
20 peroxidase, lactoperoxidase, etc.) which may be used in combination with inorganic  
alkali salts of iodide to affect *de novo* formation of elemental iodine, in a preferred  
10 embodiment, the formulation for generating *de novo* free iodine can be made up as a two-  
25 component solution in which the oxidants and inorganic iodide are kept separate from  
one another until mixing the two solutions together. Protons, or a proton-generating  
source (for example, glucose oxidase), are also included in one of the two solutions,  
30 preferably with the oxidizing agent. In the case of using an enzyme such as glucose  
15 oxidase as the proton-generating source, the substrate (vis., glucose) used to activate the  
35 reaction must therefore be provided in the alternate solution, or be present in the body  
fluid in which the device is inserted. Thereafter, the formation of *de novo* free iodine  
should ensue within no less than a few seconds, and preferably not more than about one  
40 hour, in conferring to the implant anti-infective activity. The desired endpoint is to  
20 achieve a presentation of free iodine at not less than about 2 ppm, nor more than about  
300 ppm free iodine whether this level is generated rapidly, or over more extended  
45 intervals, sufficient to kill organisms attempting to colonize the implant device and  
surrounding tissue adjacent to the implant.

5 An example of a preferred *de novo* free iodine formulation, made up in Parts "A" and "B", is as follows:

10 Part A

From about 0.1 mM to not more than about 50 mM alkaline salt of iodine made  
5 up in sterile water, with the preferred salt made up as potassium iodide.

15 Part B

From about 0.1 mM to not more than about 50 mM iodate salt made up  
preferably as sodium or potassium iodate, preferably 20 mM, in from about 0.05 to 1%  
20 B.F. Goodrich Carbopol C971, C974 or Polycarbopol, adjusted with dilute base or acid  
as required, to a pH ranging from about 3.5 to about 6.0, preferably pH 4.5, in sterile  
10 water, wherein the carbopol formulations serve as a source of protons and as a viscosity  
25 agent.

Just before use, Parts A and B are mixed together in a 1:1 ratio by volume, then  
30 loaded directly into the lumen site of the indwelling implant device as discussed above,  
or presented into a tube or reservoir in which the insert rod has been placed for loading of  
15 the newly formed free iodine into the rod prior to its insertion into the lumen of the  
device to which anti-infective activity is to be conferred. In the latter instance, the insert  
rod should be allowed to remain exposed to the iodine-generating solution until it takes  
35 on a violet to red hue indicative of iodine transfer to the solid phase of the insert rod. The  
insert rod is then removed from the solution and inserted into the inner lumen of the  
40 implant device to affect transfer of pre-loaded free iodine to the implant device.

45 Where it is desirable to exclude a viscosity agent in Part B of the formulation  
(for example, for use in an indwelling venous catheter), citrate or alkali salt phosphate  
50 buffers ranging from not less than 1 mM nor in excess of 50 mM, preferably of about 10

5 mM, ranging in pH from about 3.5 to about 6.0, preferably about pH 4.5, in sterile water,  
may be substituted in place of carbopol. The choice of the pH donor is not critical so  
10 long as the buffer system is not toxic given intravenously to the body, or not an irritant in  
coming into contact with the epithelial tissues of the body.

5 . 5 Appropriate intervals of pre-loading the insert rod, and for allowing free iodine  
15 to transfer to the implant device must be worked out on a case by case basis depending  
upon the nature of the device to be loaded, but in general the process should be  
20 completed within a period of not less than about 1 minute, nor more than about 30  
minutes to be practical in the clinical setting. If the loading formulation is to be left  
10 within the implant, or the insert rod is designed to be left in the implant lumen (i.e.,  
25 fabricated to allow fluids to flow freely around the insert and inner walls of the lumen)  
then it is only necessary to assess timing with regard to the frequency of treatments in  
preventing and/or treating implant infections linked with the insertion of the implant and  
30 its retention in the body cavity for which it is in use.

15 Hydrogels other than Carbopol may be substituted in its place in Part B of the  
35 iodine-generating formulation such as carboxy methylcellulose, hydromethylcellulose,  
hydroxypropyl cellulose, polyethylene glycols, and the like. The main purpose of the  
hydrogel is to provide a more viscous fluid in preventing rapid expulsion of the iodine-  
40 generating formulation from the site of its deposition within the lumen of the medical  
20 device to be treated with anti-infective activity. Similarly, the choice of oxidant is not  
critical providing the oxidant is stable in the aqueous formulation in providing Part B  
45 with sufficient shelf life to make its use practical for commercial use. Inorganic oxidants  
or preferred in this regard, such as iodate salts, since these salts are stable in solution as  
50

5 formulated for several months without adverse loss of oxidizing activity in converting inorganic iodide to iodine under the conditions noted above.

10 The present invention thus offers substantial flexibility in providing for stable two-component formulations which, when delivered to the inner lumenal wall of  
15 catheters, and other implant devices, fabricated from hydrophobic polymers such as silicone, polyurethane, polyvinyl chloride, or polyethylene, and similar types of medical grade polymers used commonly in medical implants devices, confer to such devices anti-  
20 infective activity. This anti-infective activity is conferred by the rapid transfer of free elemental iodine into, and across, the walls of such implant devices, presenting to  
10 exterior surfaces of such devices a concentration of iodine in excess of 2 ppm sufficient to kill microorganisms adhering and adjacent to the outer walls of the devices subjected  
25 to such treatment. Furthermore, the invention provides flexibility in dosing implant devices with anti-infective activity by allowing for *in situ de novo* formation of free  
30 elemental iodine within and about the walls of implant devices treated by the invention.  
15 Contrary to prior art, the invention teaches that binding agents, or iodophors, are unnecessary in coating the walls of implant devices to be treated, and indeed that the  
35 latter treatments are contra-indicated. Free iodine dosing and egress from the implant device, as illustrated in the accompanying examples, is easily controlled by selection of  
40 the available concentration of precursor inorganic iodide formulated in the invention which, in combination with an oxidizing agent, and proton source, ensures rapid  
20 conference of anti-infective activity to implant devices using this invention. This  
45 invention is applicable in treating existing catheter devices such as urinary catheters, venous and arterial access lines, drain tubes, as well as solid implant devices where rapid  
50 self-sterilizing activity conferred to the implant device is desirable in reducing the

incidence of infections otherwise introduced during, and after, implantation in body cavities.

#### Specific Examples

Example 1 – Effect of pH on *De Novo* Formation of Elemental Iodine Produced from Inorganic Iodide and Iodate. Fig. 1 shows the effect of varying the pH of buffered citrate solutions (50 mM) on the rate of free elemental iodine formation using potassium iodide and sodium iodate as precursors. Iodine was quantitated as the triiodide complex formed by transfer of aliquots of test reaction mixtures to stock 10 mM potassium iodide made up in distilled water measured at 350 nm on a double-beam UV-265 double beam Shimadzu spectrometer. A calibration curve was prepared using crystalline iodine dissolved in the same stock potassium iodide solution. Citrate buffered solutions were made up to known pH values as indicated, determined by titration and measurement on a standard pH meter. Aliquots of the citrate buffered solutions were mixed with silicone discs impregnated with a mixture of 2% potassium iodide and 10% sodium iodate (by weight relative to the disc). Following varying incubation periods, aliquots of the test solutions were analyzed for formation of elemental iodine as noted above from which a pH profile was constructed showing the rate of free iodine formation versus proton concentration. The optimal pH for iodine formation was observed to be approximately 4.5 regardless of the incubation interval. Samples were monitored for iodine formation from approximately 10 minutes up to 24 hours after initiation of the reaction. Fig. 1 is typical of the pH profiles observed reflecting accumulated free iodine approximately 4 hours after initiation of iodine formation.

Example 2- Egress of Iodine from Polyvinylchloride (PVC)-Loaded Catheter Tubing by ICAT. Fig. 2 shows the recovery of iodine released from PVC tubing pre-



5 loaded with varying concentrations of iodine using in-situ chemical anti-infective  
loading technology (ICAT) for iodine-generating formulations versus immersion times of  
10 the catheter in fluid. Five cm lengths of PVC tubing (outer diameter, 5.5 mm; inner  
diameter, 3.0 mm) were pre-loaded with iodine-generating formulations made up of parts  
15 A and B in which the final concentration of inorganic sodium iodide ranged from 2.5  
(solid circles), to 12.5 mM (solid squares) to 50 mM ("x" symbols), respectively. The  
final concentration of Carbopol C971 PNF was made up as 0.25%, and sodium iodate  
20 was held constant at 12.5 mM. The pH of the iodine-generating formulation was 4.6.  
Immediately after pre-loading the inner lumen of the PVC tubing, the ends were capped  
10 with glass rods (total ICAT loading volume, 0.353 ml), and the catheter tubing was  
25 rinsed with distilled water to remove any traces of iodine-generating formulation from  
the exterior surfaces. Each was then immersed in 10 ml of 10 mM KI made up in water,  
and the egress of free iodine into the latter fluid (trapped as the triiodide complex)  
30 tracked at 350 nm on a UV-265 Shimadzu double beam spectrometer at the points  
15 indicated in Fig. 2. Quantitation of the free iodine concentrations was made by  
35 constructing a calibration curve and converting milliabsorbances measured in the  
external fluid to ppm using known amounts of crystalline iodine dissolved in the same  
potassium iodide solutions. The effectiveness of the end caps used in sealing the  
40 catheters was confirmed by loading the same tubing with dye (toluidine blue) and  
20 verifying that it did not leak into the external fluid bathing the catheter. All experiments  
45 were conducted at room temperature (~ 21 - 23 ° C).

The results show an initial lag phase in the release of free iodine from the loaded  
catheter segments corresponding to approximately 10 to 12 hours, and a subsequent  
50 phase in which free iodine levels began to rise almost linearly with time with a

5 subsequent tapering off of the egress rate about 3 days after the initial loading of ICAT.

10 The rate of iodine release continued to rise gradually over an extended period of time except at the lowest loading dose used (e.g., 2.5 mM sodium iodide). In the latter case, free iodine peaked at about 55 to 60 hours after initial loading with ICAT. Peak levels of  
15 free iodine in the 10 ml external fluid volume reached the microbial killing target of about 2 ppm within the first 24 hours for sodium iodide loading doses of ICAT equal to or exceeding 25 mM. Depending upon the external fluid volume in which iodine  
20 egressing from the catheter tubing comes into contact with, it can be appreciated that more than adequate levels of microbicidal iodine were achieved to confer to the external  
10 wall and local environment potent anti-infective activity.

25 Example 3 – Uptake and Transport of Free Iodine into the Catheter Wall of ICAT-Loaded PVC Tubing. Fig. 3 shows the corresponding uptake of free iodine formed with loading of ICAT into the same PVC tubing using an identical experimental setup as  
30 in Example 2. In these experiments, ICAT loading was made using a final concentration of sodium iodide of 25 mM with sodium iodate held constant at 12.5 mM, Carbopol  
15 C971 PNF held at 0.25%, and the final pH set at 4.6. Following end capping of the PVC catheter tubing, and rinsing of the capped tubing in distilled water, the tubing was again  
35 placed in 10 ml of 10 mM KI. However, rather than monitoring the egress of iodine, at the points indicated in Fig. 3, 10  $\mu$ l aliquots of the ICAT fluid were withdrawn from the  
40 internal lumen and the level of free iodine in the latter solution determined following 100-fold dilution in 10 mM potassium iodide solution. The concentrations shown in Fig.  
20 3 thus represent 1/100<sup>th</sup> of the actual concentration of free iodine formed in the internal lumen of the catheter.

5 The results of Fig. 3 show that the free iodine concentration quickly achieved  
saturating levels of free iodine with regard to the solubility of iodine (upper limit of  
10 solubility, ~ 320 ppm) in less than a few minutes of ICAT loading, and thereafter the  
iodine concentration fell sharply over the next several hours, reaching a slower rate of  
15 decline around 40 to 50 hours after initial ICAT loading of the catheter. The attainment  
of a trough around 40 hours post ICAT loading within the internal lumen site, and peak  
egress of iodine in the range of 55 to 60 hours post ICAT loading (cf., Fig. 3), suggests  
20 that in PVC tubing the transit time of iodine passing across the walls of the catheter may  
be as long as 15 to 20 hours. This is also consistent with the initial lag phase in the egress  
10 of free iodine from the walls of the PVC catheters shown in Fig. 3. Except for the lag  
phases, Figs. 2 and 3 show inverse relationships between the clearance of free iodine  
25 from the inner luminal reservoir, and egress from the out walls of the PVC catheters as  
would be expected in a reciprocal transport process from the inner to exterior walls of the  
30 catheters. Furthermore, the high internal levels of iodine seen shortly after ICAT loading,  
15 and subsequent steep fall in iodine levels, is consistent with crystallization of iodine onto  
the inner walls of the catheter, and subsequent uptake of iodine into the PVC wall of the  
35 catheter.

40 Example 4 – Transfer of Free Iodine from a Solid-Phase Loading Platform to an  
Aqueous Solution. Fig. 4 demonstrates the kinetic transfer of free elemental iodine from  
20 a prefabricated hydrophobic polyethylene (PE) tab (dimensions, 8.5 x 0.5 x 0.05 cm  
[length x width x thickness]), loaded with free elemental iodine using the ICAT  
45 technology, to free solution (10 ml of 10 mM KI). In these experiments the PE tab was  
first exposed to ICAT (final concentration of sodium iodide, 25 mM; sodium iodate, 12.5  
50 mM; Carbopol C971 PNF, 0.25%) at room temperature for 30 minutes. During this

interval the PE tab took on a deep violet color concomitant with the formation of minute crystalline particles of iodine condensing onto its surface, and subsequent diffusion of iodine from the solid state into the PE tab. The PE tab was then removed from the ICAT iodine loading solution, rinsed in distilled water to remove any residual iodine solution adhering to the PE tab's surface, and then placed in 10 ml of 10 mM potassium iodide made up in water to track the release of free iodine. Each point on the graph shown in Fig. 4 reflects the level of free iodine recovered in the immersion fluid in which the PE tab was placed (measured as described in Example 1 at 350 nm). Microbial killing levels of free iodine in excess of 2 ppm were achieved with the solid-phase transfer platform within approximately 20 minutes of immersion of the PE tab in solution. Thereafter, free iodine accumulated in the immersion fluid over a period of approximately 60 hours after which the levels of free iodine reached a plateau at about 8 ppm in a total fluid volume of 10 ml.

These results confirm the feasibility of solid-phase transfer of free iodine from a solid-phase insert (e.g., the PE tab) to an aqueous fluid. It is anticipated that had the PE tab been constructed to insert within the luminal space of an indwelling device, that the series of transfers of iodine would progress from the solid-phase insert to the internal luminal fluid (or air phase in a free flowing urinary catheter), to the walls of the implant device, and then egress to the exterior wall of the device as illustrated in reviewing the results documented in Examples 2, 3 and 5 through 8.

#### Example 5 – Effect Pre-Loading Volume of ICAT Iodine-Generating

Formulation on Iodine Egress from Silicone Catheters. Fig. 5 shows the release rates of free iodine egressing from the exterior wall of silicone catheters pre-loaded for 20 minutes with ICAT iodine-generating formulation. Five cm lengths of all silicone

5 catheters were prepared and loaded with a final concentration of 25 mM sodium iodide  
ICAT solution made up also in 12.5 sodium iodate, 0.25% Carbopol C971 PNF, pH 4.6,  
10 capped with glass rods on the ends, and rinsed of any residual contaminating ICAT  
solution on the exterior surface of the catheters. Following a 20 minute incubation period  
15 at room temperature, the residual ICAT fluid inside the catheters were flushed out with  
distilled water, the ends of the catheters were resealed with glass rods, and the catheters  
then immersed in 10 ml of 10 mM potassium iodide made up in distilled water.  
20 Thereafter, the concentration of free iodine was tracked as a function of the immersion  
interval in the same manner as in Fig. 2. The upper tracing shows the results of iodine  
10 egress from the external walls of the catheter using a catheter with a diameter twice that  
25 of the lower tracing (total ICAT fluid volumes pre-loaded into the catheters are indicated  
to the right of each tracing).

30 The results show rapid egress of free iodine from the pre-loaded silicone catheters  
with microbial killing levels of 2 ppm were achieved for both catheters within about 40  
15 minutes of immersion after an initial 20 minute exposure of the catheter to ICAT iodine-  
35 generating formulation. Peak levels of free iodine (in a fluid volume of 10 ml) occurred  
about the third hour of immersion with a gradual falloff in the recovery of free iodine  
over the next approximate 24 hours.

40 Example 6 – Egress of Free Iodine from Silicone Catheters as a Function of  
20 ICAT Iodine Loading Dose and Immersion Interval. Fig. 6 shows the release of free  
iodine from the exterior walls of silicone catheters cut into 5 cm lengths and capped as in  
Example 2, but using varying concentrations of sodium iodide from a low concentration  
of 1.6 mM to a high of 25 mM, as indicated. The concentration of sodium iodate and  
50 Carbopol C971 PNF was kept constant at 12.5 mM and 0.25%, respectively. As in  
55

5 Example 2, after loading ICAT iodine-generating formulations into the internal lumen of  
the catheters, each was sealed with glass rods and immersed in 10 ml of 10 mM  
10 potassium iodide to allow for tracking of free iodine egressing from the exterior walls as  
a function of immersion interval.

15 The rates of iodine egress were much faster in silicone catheters relative to PVC  
catheters (cf., Fig. 2), reaching peak levels within approximately 4 hours after immersion  
of the catheters in the tracking fluid. There was also a continual rise in the release of free  
20 iodine extending beyond 24 hours of immersion for catheters loaded with ICAT  
containing sodium iodide in excess of ~ 6.5 mM (cf., Fig. 6). In addition, in all but the  
10 lowest concentration of sodium iodide used, microbial killing threshold levels of about 2  
25 ppm free iodine in 10 ml fluid volumes were achieved within roughly about one hour of  
immersion. The results show a linear proportionality between loading doses of sodium  
iodide included in the ICAT formulation and free iodine egressing from the catheters  
30 over the entire concentration range examined.

15 Example 7 – Effect of Pre-loading Interval on Recovery of Free Iodine Egressing  
from Silicone Catheters. Fig. 7 shows the effect of pre-loading interval (residence time of  
35 ICAT within the lumen) on egress of free iodine from silicone catheters prepared as in  
Fig. 2. In these experiments, 5 cm segments of silicone catheters (lumen volume, 0.2 ml)  
40 were loaded with ICAT iodine-generating formulation with the final sodium iodide  
concentration set at 25 mM, sodium iodate at 12.5 mM, and Carbopol C971 PNF at  
20 0.25%, for the intervals noted. Thereafter, the ICAT solutions were flushed free of the  
catheter with distilled water, the catheters were recapped with glass rods, then they were  
45 immersed in 10 ml of 10 mM potassium iodide and tracked for release of free iodine  
egressing from the walls of the catheter into the external fluid at 4 hours after immersion.  
50

5 A near linear relationship between pre-loading interval and the recovery of free  
iodine within the external fluid bathing against the capped catheters is shown. Microbial  
10 killing levels of free iodine in excess of 2 ppm were achieved within approximately 5  
minutes exposure of the catheters to ICAT. These results indicate that even brief  
5 exposure to ICAT iodine-generating formulations is sufficient to confer to indwelling  
15 walls of silicone type implant devices iodine-mediated anti-infective activity (see  
Background of the Invention).

20 Example 8 - Egress of Iodine from Silicone Catheters versus ICAT Iodine  
Loading Dose and Immersion Interval in the Absence of a Hydrogel Viscosity

10 Augmentor and Comparison with Commercial Povidone-Iodine Used in Place of ICAT.  
25 The egress of free iodine was examined as in Example 6 using ICAT formulations, but  
with replacement of carbopol in Part B of the formulation with 25 mM potassium citrate  
buffer adjusted to a final pH of 4.2. Fig. 8 shows the egress of free iodine as a function  
30 of potassium iodide concentration in ICAT solutions varying from 6.3 to 50 mM. The  
15 initial concentration of sodium iodate in each test was held constant at 12.5 mM.  
35 Qualitatively the release of iodine from the capped silicone tubing is very similar to that  
seen with carbopol wherein the release kinetics peaked at approximately 4 hours after  
loading the inner lumen with ICAT solutions. The data demonstrate that the level of free  
40 iodine egressing from the walls of the catheter can be adjusted over a wide range of doses  
20 from a low of a few ppm to in excess of 50 ppm (in a 10 ml suspension). Hence, total  
free iodine released within the first 4 hours exceeded 500 micrograms per 5 cm segment  
45 of silicone tubing loaded with ICAT solution. This contrasts sharply with the marginal  
release of no more than a few micrograms of free iodine over the same interval using  
50 silicone catheters loaded with 10% Povidone-iodine (cf., Fig. 8, bottom tracing). It can

5 be seen from an examination of the experimental data (cf., Fig. 8) that within the first  
hour of treatment that the level of free elemental iodine egressing from the catheter  
10 tubing using ICAT exceeded that detected using 10% Povidone-iodine by a factor in  
excess of 50-fold. During this interval, the concentration of free iodine recovered in the  
5 suspending medium barely reached 0.4 ppm using Povidone-iodine as the means of  
15 transferring iodine to the walls of the silicone catheter, a concentration well below the  
necessary threshold of about 2 ppm required for effective antimicrobial activity (cf.,  
20 LeVeen et al. (1993) Gynecology & Obstetrics 176: 183-190). This contrasts sharply  
with levels of free iodine measured in the external medium using ICAT as the loading  
10 vehicle which, under the same experimental conditions, yielded concentrations ranging  
25 from a low of 8 ppm to a high of 20 ppm, depending upon the initial formulation of  
inorganic iodide used (cf., Fig. 8).

Example 9 – Conveyance of Anti-infective Activity to a McComb Neonatal  
30 Catheter and Effect of Varying Potassium Iodide Concentrations in Affecting Iodine  
Uptake into the Catheter. To test the efficacy of transiently loading iodine into the  
15 polymer base of a neonatal McComb catheter (Model NNCR3, Phoenix Biomedical  
35 Corp, Valley Forge, PA) using ICAT, solutions were made up at varying concentrations  
(final concentration after mixing parts A & B together) of potassium iodide as indicated  
40 in Fig. 9 while holding the final concentration of sodium iodate and potassium citrate at  
20 12.5 and 25 mM, respectively. The solutions were buffered to pH 4.2. The McComb  
catheter is a drain tube designed for treatment of hydrocephalus. It has an outer diameter  
45 of 2.1 mm, and inner diameter of 1.0 mm, a length of 3 cm, and a small inner reservoir  
holding about 0.15 ml fluid volume, all fabricated out of a platinum catalyzed silicone  
50 base polymer, and backed by a polyester patch for suturing at its implant site within the



5 brain. It comes with a nylon plug which can be inserted into the reservoir aperture to  
block fluid travel through the inner lumen. The catheter was submerged in ICAT  
10 solutions of varying potassium iodide concentration prepared fresh at room temperature  
and incubated for 20 minutes. Thereafter, the catheter was rapidly rinsed in distilled  
5 water and transferred to 10 ml solutions of 10 mM potassium iodide placed inside a  
15 capped polycarbonate tube. At varying intervals the egress of pre-loaded iodine taken up  
by the catheter was measured as the tri-iodide complex spectroscopically at 350 nm. Fig.  
20 9 shows a dose dependent relationship between available potassium iodide made up in  
the ICAT solutions and the recovery of iodine transferred to the polymer base and  
10 subsequently released into solution following the pre-loading interval of 20 minutes. In  
25 these measurements the inner reservoir of the catheter was capped with the nylon plug so  
that only the egress of iodine from the exterior side of the catheter was tracked. The  
egress rate from the exterior side of the catheter of iodine pre-loaded onto the catheter  
30 peaked around 30 minutes.

15 Fig. 10 shows that with increasing concentrations of potassium iodide included in  
the ICAT formulation, there was an actual decrease in loading efficiency of free iodine  
35 into the walls of the polymer evident by a bell shaped curve. The maximum recovery of  
iodine peaked around 30 mM potassium iodide yielding about 30 ppm free iodine (in a  
40 10 ml fluid volume) coming back off of the polymer base approximately 40 minutes after  
20 rinsing the catheter free of ICAT solution. The bell shaped curve affirms that loading is  
most efficient wherein iodine is in an unbound form. Hence, at the higher concentrations  
of iodide formulated into the ICAT solution where the molar ratio of iodide to iodate  
45 exceeds about 2.5, a significant portion of the iodine formed is complexed as tri-iodide  
which does not readily allow for the transfer of iodine into the walls of the catheter. This  
50

5 observation reaffirms that iodophors, or complexes of free iodine as in Lugol type  
solutions where tri-iodide is a dominant component, teaches away from the correct art of  
10 striving to optimize the generation of a preponderance of free iodine in maximizing its  
transfer to polymeric implant devices.

15 To verify microbial killing, the McComb catheter was pre-loaded with ICAT  
containing a final concentration of 25 mM potassium iodide, 12.5 mM sodium iodate,  
and 25 mM potassium citrate, pH 4.2, for 20 minutes at room temperature, then  
20 thoroughly rinsed 10 times in sterile distilled water to remove any traces of residual  
ICAT solution adhering to the catheter walls. *Staphalococcus epidermidis* ( $\sim 10^4$  CFU) in  
10 a total volume of 0.13 ml suspended in isotonic saline, and in BHI medium (pH 7), was  
then loaded into the inner reservoir of the catheter, and at one hour and four hours after  
25 loading the catheter the inner reservoir was cultured on blood agar plates for surviving  
organisms. In isotonic saline all of the organisms were killed within the first hour  
30 following introduction of cultures to the ICAT treated catheter. Cultures suspended in  
15 BHI media were not killed within the first hour, but by four hours no detectable  
organisms were recovered from the inner reservoir indicating complete killing by this  
35 time. The delayed killing seen in BHI medium appears to be attributable primarily to the  
high reducing equivalents in the medium which neutralizes some of the free iodine pre-  
40 loaded into the walls of the catheter. Nevertheless, the sustained release of iodine taken  
20 up into the walls of the catheter within the first 20 minute ICAT treatment ultimately  
succeeded in killing the organisms as noted in the four hour sampling of the reservoir  
45 chamber.

Example 10 – Transfer of Nascent Iodine across the Walls of Inflatable Balloons  
50 Built into Latex and Silicone Foley Catheters. Since many implant devices use inflatable

5 balloons to hold the implant in place, the efficacy of transferring nascent iodine (formed  
by ICAT) across the walls of the balloon to confer to the external side of the implant  
10 anti-infective activity was examined. Foley catheters were inflated through a valve  
familiar to those using this type of device. In this example, ICAT solutions were  
5 substituted in place of distilled water, allowing for the transfer of nascent iodine across  
15 the walls of the catheter and balloon. The addition of ICAT to the balloon involved the  
same process used in filling the balloon with distilled water, namely injection of fluid  
20 using a needle-free Luer-lock syringe placed into the value and expression of fluid  
through the cannular line communicating with the balloon. Fig. 11 illustrates the design  
10 of the catheter allowing for inflation of the balloon with ICAT. The small arrows  
25 perpendicular to the plane of the catheter and walls of the balloon represent lateral egress  
of nascent iodine from the external walls of the catheter. In this design only nascent, anti-  
infective, free iodine, egressing laterally across the walls of the catheter, comes into  
30 contact with body fluids and tissues, and upon egress sterilizes the latter external sites  
15 proximal to the catheter.

35 In this example, ICAT can be used to provide transient delivery of nascent iodine  
across the walls of the catheter through the inner lumen communicating with the balloon,  
and the walls of the balloon, itself (cf., Fig. 11). Iodine egressing in this manner into  
40 urine contained in the bladder thus serves to sterilize the bladder, providing a means of  
20 therapeutically treating cystitis. It also serves to sterilize the urethral canal through which  
the Foley catheter travels. This occurs as iodine moves laterally across the luminal wall  
45 in communicating fluid to the balloon, but also as iodine delivered to the bladder urine  
travels down the central lumen of the Foley catheter toward the waste line.

Fig. 15 shows the kinetic egress of nascent iodine from the external balloon walls of Foley catheters made of silicone (dashed line) and latex (solid line) inflated with ICAT. The ICAT solutions were formulated at a fixed concentration of iodate (12.5 mM) and potassium citrate (25 mM), and potassium iodide was adjusted to either 30 mM (solid symbols), or 15 mM (open symbols). To initiate transfer of nascent iodine formed by ICAT to the Foley catheters, 5 ml of "Part A" ICAT (either 30 or 60 mM potassium iodide made up in distilled water, as indicated below) was premixed with 5 ml of "Part B" ICAT (50 mM potassium citrate, pH 4.2, made up in 25 mM sodium iodate in distilled water). This mixture was immediately transferred to a 10 ml Luer-lock syringe and injected through the valve of the Foley catheter resulting in inflation of the catheter balloon with ICAT. Nascent iodine begin forming immediately upon mixing Parts A and B ICAT solutions together, and continued to form over the next approximate four hours while the mixture resided within the inflated balloon of the Foley catheter.

For the latex catheters, standard 16 Fr. 5 cc ribbed balloon "Lubricious" Foley coated catheters were used (BARDEX® LUBRICATH® Foley Catheters, C.R. Bard, Inc., Covington, GA 30014). For silicone, 16 Fr. 5 cc silicone Foley catheters obtained from the same manufacturer were used (BARDEX® All-Silicone Foley Catheters, C.R. Bard, Inc., Covington, GA 30014). Each catheter was inflated to 10 ml in volume in accordance with the volume recommendations of the catheter manufacturer, substituting ICAT in place of distilled water. The inflated balloon was then submerged beneath 100 ml 10 mM potassium iodide within a glass jar in which a magnetic mixing bar was also included to facilitate uniform mixing and sampling of solution coming into contact with the external side of the balloon wall. The remaining portion of the catheter was draped above the glass jar in a manner excluding any possibility of siphoning or leakage of

5 ICAT solution loaded through the valve from gaining access to the potassium iodide-  
iodine trapping solution. At the times indicated, aliquots of the potassium iodide-iodine  
10 trapping solution bathing the balloon were drawn for measurement of nascent iodine  
egressing into the solution where it formed upon contact with the external solution a tri-  
15 iodide complex. Formation of tri-iodide was tracked spectrally at 350 nm. Free iodine in  
the external trapping solution was calculated by comparing the absorbency of test  
samples against that obtained for a standard curve calibrated with iodine of known  
20 concentrations added to stock potassium iodide solutions.

Peak levels of free iodine in ICAT inflated catheters occur approximately four  
10 hours after loading of ICAT into the balloon (cf., Fig. 15). The sharp falloff in nascent  
25 iodine thereafter reflects loss of free iodine into the atmosphere as iodine escapes from  
the trapping solution during the course of these measurements. Hence, accounting for the  
loss of nascent iodine to the atmosphere, it is apparent that substantial concentrations of  
30 free iodine in excess of 50 ppm (in a 100 ml fluid volume) for silicone catheters, and 30  
15 ppm for latex catheters, was achieved. Furthermore, the dosage is adjustable depending  
upon the concentration of inorganic iodide formulated in stock ICAT solution (Part A).  
Thus, this data demonstrates the feasibility of adjusting the dosage of nascent iodine  
delivered to the external side of the Foley catheters through introduction of ICAT to the  
40 inflatable balloon used to anchor the catheter at the base of the bladder. While in pure  
20 solutions only a few ppm free iodine are required to render a site sterile, this type of  
flexibility in dosing the catheter is necessary to compensate for naturally occurring  
reducing equivalents present in urine, and other body fluids, in contact with the walls of  
the catheter. Hence, through clinical evaluation and an appropriate dosage can be chosen  
50 through the frequency of ICAT delivery to the balloon, and through deliberate

manipulation of the initial concentration of iodide formulated in ICAT solutions activated with mixing of Parts A and B of the stock formulation.

Example 11 – Method for Delivery of Anti-Infective Iodine to Vascular Access Lines at Doses Sufficient to Kill Microbes Adhering and Propagating on Access Lines and Implant Ports while Maintaining Safe Dosage for Direct Presentation to Blood and Systemic Circulatory System: Since all materials used for the *de novo* generation of free iodine using ICAT are natural constituents of the body, the salient issue regarding safety to the user while achieving anti-infective activity is to ensure that total daily iodine exposure to the body does not exceed a range significantly above the generally regarded safe threshold (e.g., no more than 2-fold this threshold). Effective microbial killing occurs at not less than 0.1 ppm free iodine, preferably 5 to 10 ppm. However, the presence of reducing substances in blood and body fluids consumes free iodine, converting it to inorganic iodide. Hence, measures are required to compensate for reducing substances in blood and body fluids to achieve a final concentration of free iodine within the range stated above, or higher, to affect microbial killing and sterilization of the implanted access line, or implant port. However, an upper daily threshold for total iodine exposure of  $\leq 1000$  micrograms per day is generally agreed to pose no significant health threat to human health. The principal target of excess and chronic iodine exposure is the thyroid gland wherein excess total body iodine exposure can lead to a multitude of thyroid disorders including, with chronic exposure, hyper- and hypo-thyroidism.

TABLE 1. Representative Vascular Access Line and Implant Port Inner Lumen Volumes.

Catheter	Inner Diameter (cm)	Length (cm)	Vol. (ml)
Hohn 4F Single-Lumen CVC	0.07	34	0.131
Hohn 5F Single-Lumen CVC	0.09	34	0.216
Hohn 7F Dual-Lumen CVC	0.08	36	0.181
Hohn 7F Dual-Lumen CVC	0.1	36	0.283
SLIMPORT® Implant Port	0.13	75	0.995
ROSENBLATT Dual SLIMPORT® Implant Port	0.1	75	0.589
PER-Q-CATH® (Dual-Lumen) PICC	0.03	60	0.042
PER-Q-CATH® (Dual-Lumen) PICC	0.063	60	0.187

Table 1 illustrates that vascular access lines (cf., central venous catheters (CVC) and peripherally inserted central venous catheters (PICC)), and implant ports (cf., SLIMPORT® and ROSENBLATT implant ports) have small diameters by design as an essential aspect in allowing for these devices to be inserted into a body blood vessel for delivery of medications and sampling of the systemic blood system. Hence, the total inner luminal volume of such devices is small and can be calculated as  $\pi \times r^2 \times L$  where the equation represents the well-known geometrical calculation for the volume of a cylinder,  $r$  = the radius of the inner diameter of the implant lumen, and  $L$  = the length of the implant device. Using these calculations it can be seen that the total volume of the inner lumens of the representative implant devices cited in Table 1 range from 0.042 ml to approximately 1 ml.

The total iodine load presented by direct delivery of ICAT into the inner lumen of a device can be calculated as the volume flushed into the device multiplied by the concentration of total iodine (free iodine, inorganic iodide, and oxides of iodide) in the

ICAT solution. Based upon the small internal lumen size of vascular access lines and implant ports (cf., Table 1), and the calculation noted, the safe daily thresh-hold of total iodine presented to the implant of  $\leq 1000$  micrograms per treatment on any given day (1 ppm = 1 microgram per ml) in the delivery of free iodine poses no significant safety hazards to a user in terms of iodine exposure. This can be seen for ICAT formulated at 12.5 mM sodium iodate, 30 mM sodium iodide, and 12.5 mM sodium citrate, pH 4.2, for example, which generates up to 200 to 300 ppm free iodine within approximately 20 minutes of activation. Since total iodine for this formulation for a 1 ml volume of the ICAT mixture is 2697 micrograms iodine, diluting this solution ten-fold in isotonic saline (0.9% sodium chloride) before infusion, and then delivering 1 ml of the diluted solution to the device lumen, allows for presentation of about 20 to 30 ppm free iodine to the inner lumen of the implant device while presenting a total body iodine exposure of no more than approximately 270 micrograms.

To rid the lumen of the implant (e.g., catheter) of reducing substances, the implant should first be flushed with isotonic saline. In this manner, microbes present in the lumen, or attached to the outer wall of the implant, can be killed as free iodine diffuses into the implant, and across the walls of the implant to the external surface. The treatment can be used at regular intervals, as necessary, to confer to vascular access lines, and ports, anti-infective activity.

Example 12 – Reduction of Total Iodine Body Dose by Insertion of a Volume Occupying Insert within a Lumen to be Conferred with ICAT Anti-Infective Activity. Alternatively, where the diameter of the lumen requiring ICAT treatment, or the length of the access lumen, is such that the total volume of fluid occupying the lumen precludes safe delivery of ICAT without exposing the user to levels of iodine in excess of 1000



micrograms per day, treatment of the lumen can be accomplished by insertion of a space occupying insert within the central lumen. As noted in Example 11, a 10 ml solution of ICAT formulated as indicated contains a total iodine dose of 26968 micrograms, more than 25-fold the upper thresh-hold of ~ 1000 micrograms to be taken in on a daily basis.

The insert can be designed, however, to displace volume in the lumen to ensure that the total fluid volume with ICAT delivered to the lumen treatment site is not less than 0.1 ml, nor more than 0.5 ml. In this manner, upon placement of the volume occupying insert within the central line, only the peripheral space between the insert and inner walls of the lumen receive ICAT treatment, and thus the total body exposure to iodine poses no health hazard since the iodine dosage delivered to the lumen cannot exceed an upper limit of approximately 1348 micrograms (e.g., 0.5 ml of ICAT solution), a level of no significant health risk to the user. This level of iodine exposure meets the essential element requirements of the body for iodine, yet free iodine formed in the range of 200 to 300 ppm is sufficient to kill microbes on the surface of the inner wall of the lumen device, and to pass through the walls of the lumen in treating bacteria which may also seed on the outside wall of the device.

The fact that the insert may touch sections of the inner wall of the lumen does not preclude conveyance of anti-infective activity throughout the walls of the device since free iodine diffuses freely within the hydrophobic polymer base of the device, filling in where direct access is not possible because of steric positioning of the insert against the lumen wall. In one embodiment, the insert has a configuration similar to the oxidant-releasing member as discussed above and illustrated in Figs. 13-14, except it preferably comprises an iodine impenetrable material, such as stainless steel, to thereby occupy space without absorbing free iodine generated by the ICAT.

5 Preferably the insert should occupy the full length of the lumen to be treated,  
contain a rounded tip to allow it to slide freely through the central lumen line in which it  
10 is inserted. The actual cross-sectional shape is not critical so long as the difference  
between the inner volume occupied by the insert and the total volume of the lumen is not  
5 greater than approximately 0.5 ml, or adjusted to ensure that total iodine dosage does not  
15 exceed approximately 1000 micrograms per treatment. The physical dimensions of the  
insert can be calculated relative to the lumen volume by the equation:

$$\text{Volume ICAT Delivered} = \text{Total Lumen Volume} - \text{Insert Volume}$$

20 Preferably the diameter of the insert should not be greater than 95%, nor less than  
10 10% of the lumen diameter to allow for ease of insertion and removal. Diameters that are  
25 less than 10% of the lumen diameter do not occupy significant space, as a general rule, to  
justify using as an insert probe.

30 In the case of a round lumen of radius,  $r$ , of given length,  $L$ , wherein the insert  
occupies 80% of the lumen space, ICAT volume delivered to the lumen in conferring  
15 anti-infective activity to the lumen can be calculated as:

$$\text{Volume of ICAT Delivered} = \pi \times (0.1r)^2 \times L$$

35 The total body exposure to iodine may be calculated by summing the concentrations of  
iodide precursors, multiplied by the molecular fraction of iodide comprising each  
40 precursor in the ICAT formulation, multiplied by the volume of ICAT delivered to the  
20 treated lumen.

45 Example 13 – Modulation of Free Iodine Egress from the External Walls of an  
ICAT-Loaded Urinary Catheter through Establishment of an Equilibrium Binding Agent  
within the ICAT Formulation. The egress rate of free iodine across the walls of the  
50 balloon can be retarded by placing a binding agent within the liquid ICAT formulation

5 within at least a section of the medical device, such as within the catheter balloon. The  
principle of modulating the egress rate through this manner is based upon setting up two  
10 competing sites for sequestration of iodine, the first the walls of the balloon, and  
subsequent external solution bathing the balloon into which iodine egresses, and the  
15 second, an iodine binding agent contained within the balloon. The latter establishes an  
equilibrium condition between free and bound iodine within the balloon, preserving and  
slowing down the egress of iodine from the walls of the balloon. This occurs where the  
20 binding agent is either chemically charged and therefore restricted from freely passing  
across the walls of the inflated balloon, where binding agent is immiscible with the  
10 polymer base making up the balloon device, or where the binding agent is of too large of  
25 molecular weight to freely permeate across the balloon wall. It is reasonably assumed  
that once iodine escapes to the wall of the balloon, it will pass freely to the external  
30 solution bathing the balloon, resulting in an overall net loss of free iodine contained  
within the balloon. As the concentration of the binding agent contained within the ICAT  
15 formulation is increased to sequester a greater proportion of free iodine formed in  
35 solution, then the iodine egress rate will be retarded based upon the Law of Mass Action  
and the basic principles in diffusion in which the rate of diffusion from a specific site is  
proportional to the concentration of the substance at that site. Suitable iodine binding  
40 agents contained within the balloon of the catheter may include silicone or mineral oils,  
20 cadexomers (carbohydrate complexes of iodine), polyvinylpyrrolidones (PVP), or other  
hydrophobic materials dispersed in the iodine-generating formulation in a manner to  
represent a reservoir in binding, and thereby retarding, the egress of iodine across the  
catheter wall.

Fig. 16 shows the effect of varying the concentration of PVP (average molecular weight, 40,000) made up in Part A of an ICAT formulation containing also 60 mM sodium iodide, and a Part B formulation made up as 25 mM sodium iodate, and 25 mM sodium citrate, pH 4.2, mixed in equal volumes with one another to initiate formation of free iodine. The final volume of the ICAT mixture injected through the Luer-lock in inflating the catheter balloon was 10 ml. The balloon was then submerged under 100 ml of 10 mM sodium iodide, and the egress of free iodine trapped as a tri-iodide complex in the external solution, then measured spectroscopically at 350 nm against iodine standards also prepared in the same 10 mM sodium iodide solution used to trap egressing free iodine. At each point, the catheter was rinsed and submerged in a fresh 100 ml of sodium iodide, so that at approximately 24 hour intervals over the course of 22 days the egress rate of free iodine was tracked. As can be seen in Fig. 16, increasing the concentration of PVP from 1% to a high of 10% (weight per unit volume) within the ICAT formulations resulted in a flattening of the peak egress rate of free iodine from the external walls of the balloon (evident by the recovery of free iodine in the solution bathing the balloon), and a shift of the peaks progressively to the right. This aspect has the benefit of preserving a sustained rate of free iodine egress over a longer interval with a single loading of the catheter balloon, sustaining anti-infective activity through continuous release of free iodine over longer treatment intervals. Beyond 8 to 10 days, the egress rates for free iodine in PVP fortified ICAT solutions was far less dependent upon PVP concentration, reaching a final equilibrium condition beyond 10 days between about 1 and 2 ppm per 100 ml sodium iodide bathing solution.

In the preferred embodiment the final concentration of PVP should be adjusted to about 2 % by weight in ICAT formulations generating free iodine *de novo*, but may

5 range from a low of about 1% to a high of about 10% by weight per unit volume of ICAT  
solution. Other iodine binding agents may also be used wherein the fundamental  
10 principle of extending the egress rate of free iodine from the external walls of the urinary  
balloon catheter is retarded by the presence of equilibrium reservoirs within the interior  
5 of the balloon competing with equilibrium reservoirs outside the balloon. In this  
15 embodiment, outside the balloon includes the walls of the balloon where it is no longer  
possible for iodine, once crossing into this region, to bind to the binding agent contained  
20 within the ICAT solution held within the balloon interior. In an alternative embodiment,  
a binding agent may be provided in the wall of the balloon or as a coating thereon.  
10 Although discussed in terms of a binding agent within an interior of a balloon, it should  
25 be understood that the ICAT formulations having a binding agent may be provided  
within the interior of a variety of catheter or medical device components, such as a  
30 catheter shaft, as discussed herein.

## Claims

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## IT IS CLAIMED:

1. A method of providing anti-infective activity to a medical device, comprising
  - a) providing a medical device which is at least in part within a patient;
  - b) exposing the medical device to an anti-infective oxidant; and
  - c) transferring the anti-infective oxidant into a wall of the medical device.
2. The method of claim 1 wherein the medical device has a lumen, and including exposing a wall defining the lumen to the anti-infective oxidant.
3. The method of claim 2 wherein the medical device is a catheter having a shaft defining the lumen and having a balloon with an interior in fluid communication with the lumen of the catheter shaft, and including exposing an inner surface of the balloon to the anti-infective oxidant.
4. The method of claim 2 including delivering a formulation which generates the oxidant in the lumen of the medical device.
5. The method of claim 4 including inserting a tubular delivery member into the lumen of the medical device, the tubular delivery member having a lumen configured to deliver the oxidant-generating formulation into the lumen of the medical device.
6. The method of claim 4 including, as a last step, removing the oxidant-generating formulation from the lumen of the medical device.

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7. The method of claim 4 including inhibiting expulsion of the oxidant-generating formulation from the lumen of the medical device by providing a viscosity increasing hydrogel in the oxidant-generating formulation.

8. The method of claim 4 wherein the anti-infective oxidant comprises elemental iodine, and including combining a first solution comprising an iodide and a second solution comprising an iodate such that an elemental iodine-generating formulation is produced, and delivering the elemental iodine-generating formulation to the lumen of the medical device.

9. The method of claim 4 wherein the anti-infective oxidant comprises elemental iodine and the oxidant-generating formulation comprises an iodide and an oxidoreductase, and including exposing the oxidoreductase to a substrate to generate protons or an iodide oxidizing agent, so that the oxidant-generating formulation produces elemental iodine.

10. The method of claim 9 including exposing the medical device to a body fluid having the substrate to generate protons or an iodide oxidizing agent, so that the oxidant-generating formulation produces elemental iodine when contacted with the body fluid.

11. The method of claim 4 wherein the anti-infective oxidant comprises elemental iodine and the oxidant-generating formulation comprises an iodate, and including exposing the iodate to a reducing agent to generate elemental iodine.



5 12. The method of claim 2 including inserting an oxidant-releasing member into the lumen of the medical device.

10 13. The method of claim 12 wherein the oxidant-releasing member has an elongated  
15 body configured to be slidably inserted into the lumen of the medical device, and further including, before step (b) of claim 1, exposing the oxidant-releasing member to a formulation which generates the oxidant so that the oxidant diffuses into the oxidant-releasing member.

20 14. The method of claim 13 wherein the anti-infective oxidant comprises elemental iodine, and including exposing the oxidant-releasing member to an elemental iodine-generating formulation comprising an iodide, an iodate, and a proton source.

25 15. The method of claim 14 including transferring about 2 ppm to about 300 ppm of the oxidant from an exterior surface of the medical device to the patient.

30 16. The method of claim 1 including, as a last step, diffusing the oxidant to an outer surface of the medical device.

35 17. The method of claim 1 wherein the anti-infective oxidant comprises elemental iodine, and including transferring about 2 ppm to about 300 ppm of the elemental iodine from an exterior surface of the medical device to the patient.

5 18. The method of claim 1 including transferring the anti-infective oxidant within  
about 1 to about 30 minutes.

10 19. The method of claim 1 wherein the anti-infective oxidant is elemental iodine, and  
5 including preventing the binding of the elemental iodine within the wall of the medical  
15 device.

20 20. The method of claim 19 wherein the binding of the element iodine is prevented  
by providing a medical device which is free of iodine binding agents.

10 21. The method of claim 4 wherein the formulation includes a binding agent which is  
25 bindable to the anti-infective oxidant, and including binding an amount of the generated  
anti-infective oxidant to the binding agent to thereby inhibit transfer of the bound anti-  
30 infective oxidant into the medical device wall.

15 22. The method of claim 21 wherein the binding agent is selected from the group  
35 consisting of silicone oil, mineral oil, cadexomers, and polyvinylpyrrolidone, and  
including increasing a duration over which at least about 2 ppm of the anti-infective  
40 oxidant is transferred into the medical device wall.

20 23. The method of claim 21 wherein the anti-infective oxidant comprises elemental  
45 iodine, the binding agent comprises polyvinylpyrrolidone, and the polyvinylpyrrolidone  
is about 1% to about 10% weight per unit volume of the formulation, and including  
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5 increasing a duration over which at least about 2 ppm of the elemental iodine is  
transferred from an exterior surface of the medical device to the patient.

10 24. The method of claim 4 including positioning an insert member into the lumen of  
the medical device to thereby reduce the amount of formulation delivered into the  
15 medical device lumen.

20 25. An anti-infective oxidant-releasing member, comprising an elongated body  
configured to be slidably disposed within a lumen of a medical device and an anti-  
10 infective oxidant releasably contained within the elongated body.

25 26. The anti-infective oxidant-releasing member of claim 25 wherein the elongated  
body comprises a solid rod.

30 27. The anti-infective oxidant-releasing member of claim 26 wherein the solid rod  
15 further includes at least one channel on an outer surface of the rod configured to allow  
35 fluid flow therein.

40 28. The anti-infective oxidant-releasing member of claim 25 wherein an outer  
20 diameter of the elongated body is about 90% to about 5% less than an inner diameter of  
the lumen of the medical device.  
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29. The anti-infective oxidant-releasing member of claim 25 wherein an outer  
diameter of the elongated body is about 20% less than an inner diameter of the lumen of  
10 the medical device.

15  
30. The anti-infective oxidant-releasing member of claim 25 wherein the oxidant  
comprises elemental iodine.

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31. The anti-infective oxidant-releasing member of claim 26 wherein the elongated  
body is formed of a polymeric material, and wherein elemental iodine is diffusible within  
10 the polymeric elongated body.

25  
32. A method of providing anti-infective activity to a medical device, comprising

30  
a) exposing the medical device to a solution which produces an anti-  
infective oxidant; and

15  
b) transferring a sufficient amount of anti-infective oxidant into a wall of the  
35 medical device to provide the medical device with anti-infective activity.

40  
33. The method of claim 32 wherein the solution is aqueous and the anti-infective  
oxidant is elemental iodine.

20  
34. The method of claim 33 wherein the aqueous solution produces at least about 0.1  
45 ppm of elemental iodine.

5 35. The method of claim 33 including transferring about 2 ppm to about 300 ppm of the elemental iodine from an exterior surface of the medical device to the patient.

10 36. The method of claim 35 wherein step (a) of claim 32 further comprises exposing  
5 the medical device a single time to the aqueous solution.

15 37. The method of claim 36 wherein the aqueous solution produces about 2 ppm to about 10 ppm of iodine.

20 38. The method of claim 33 including transferring not greater than about 1000 micrograms a day of the elemental iodine from an exterior surface of the medical device to the patient.

30 39. A method of providing anti-infective activity to a medical device, comprising  
15 a) exposing an oxidant-releasing member to a formulation which generates an anti-infective oxidant, so that the anti-infective oxidant diffuses into the oxidant-releasing member; and  
35 b) exposing the medical device to the oxidant-releasing member so that the anti-infective oxidant diffuses from the oxidant-releasing member into a wall of the  
40 medical device.  
20

45 40. An anti-infective medical device having a wall, said device being designed for introduction into the body of a patient, at least a portion of said device, and said wall, being in contact with an anti-infective oxidant.  
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41. A method of dis-infecting a medical device for administration to the body of a patient, said device having a wall, said method comprising

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a) exposing the medical device in its administered state to an anti-infective oxidant, and

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5 b) bringing said oxidant in contact with said wall.

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42. A method of controlling the microbial growth on a surface of a medical device for administration to the body of a patient, said device having a wall, said method comprising

25

10 a) exposing the medical device in its administered state to an anti-infective oxidant, and

30

b) bringing said oxidant in contact with said wall.

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43. The use of an anti-infective oxidant in the dis-infection of a medical device according to any one of claims 1 to 42.

40

44. The administration of a medical device according to any one of claims 1 to 42 to a patient.

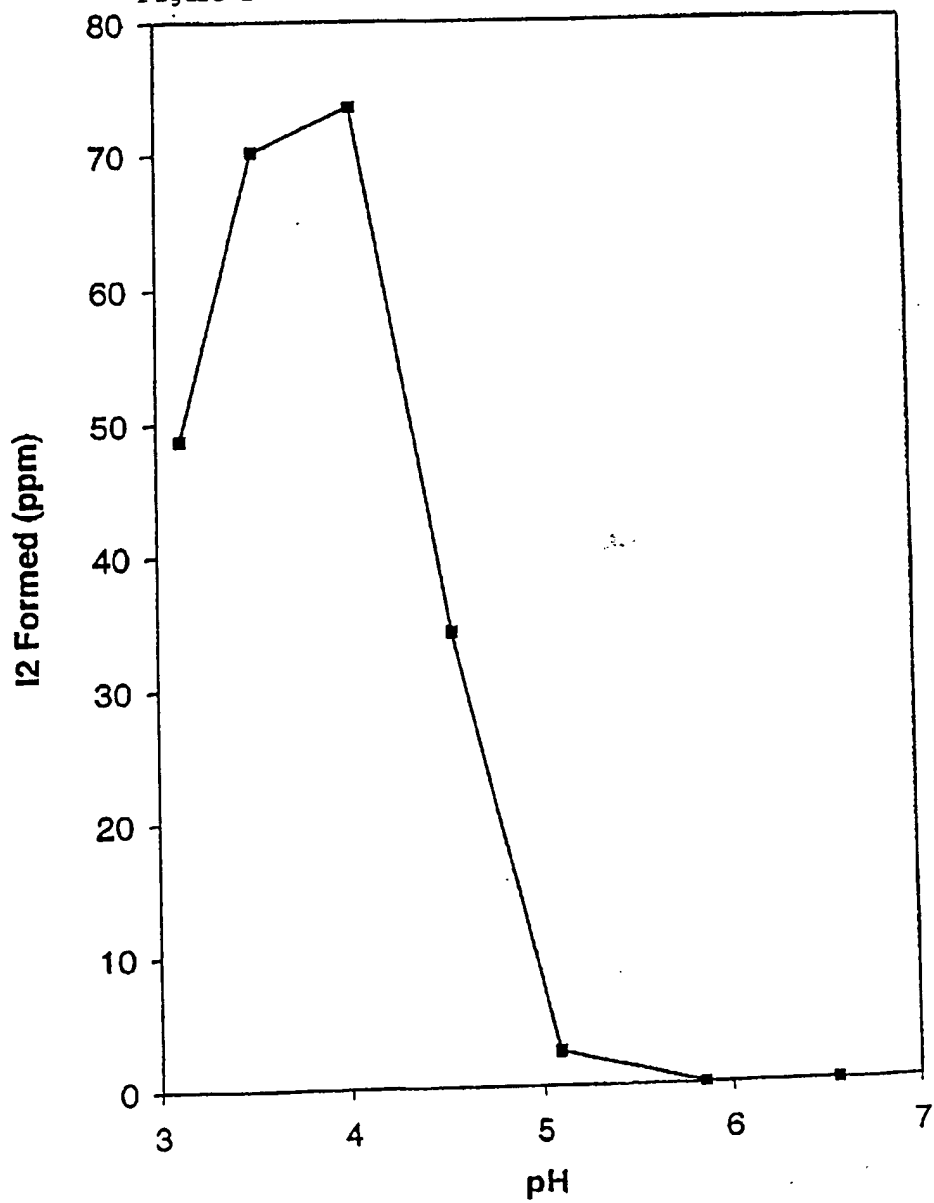
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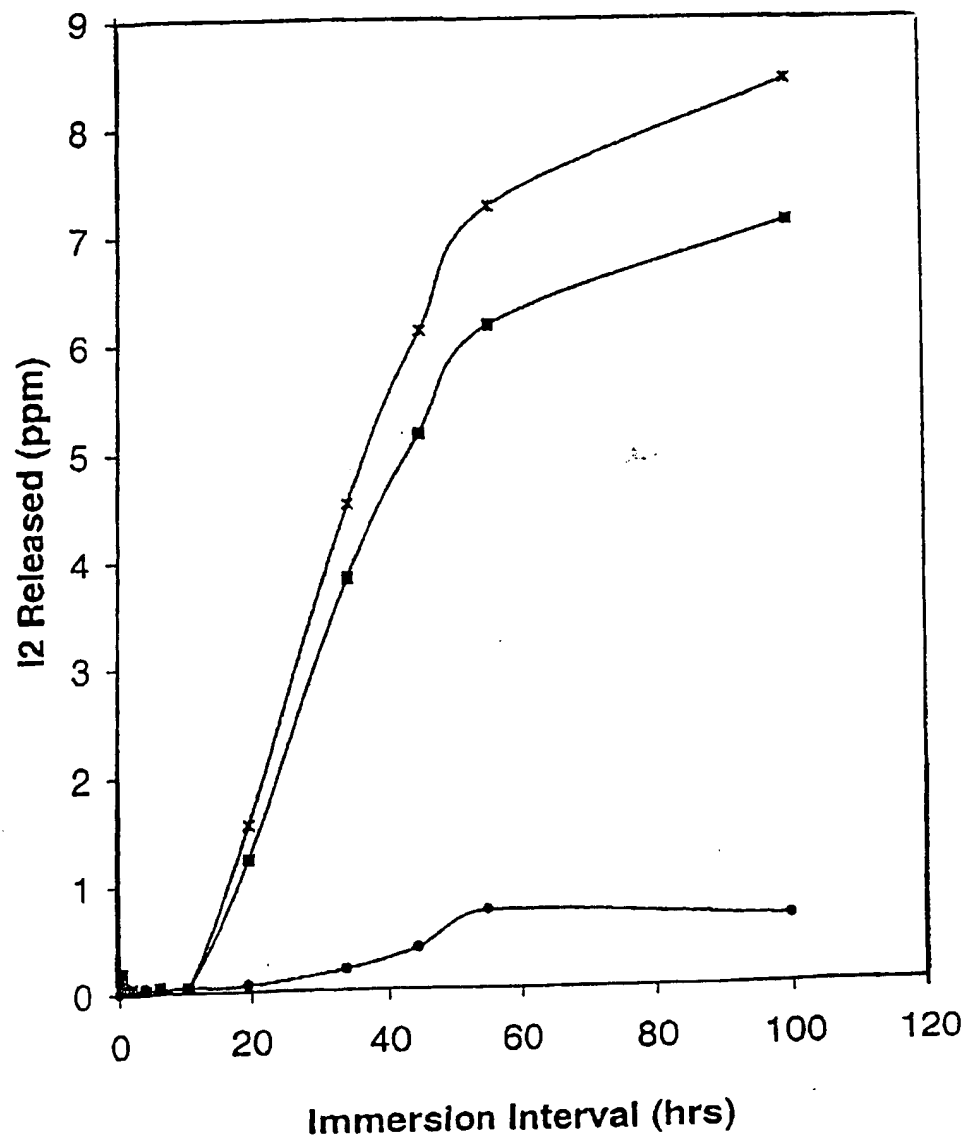
1/14

Figure 1



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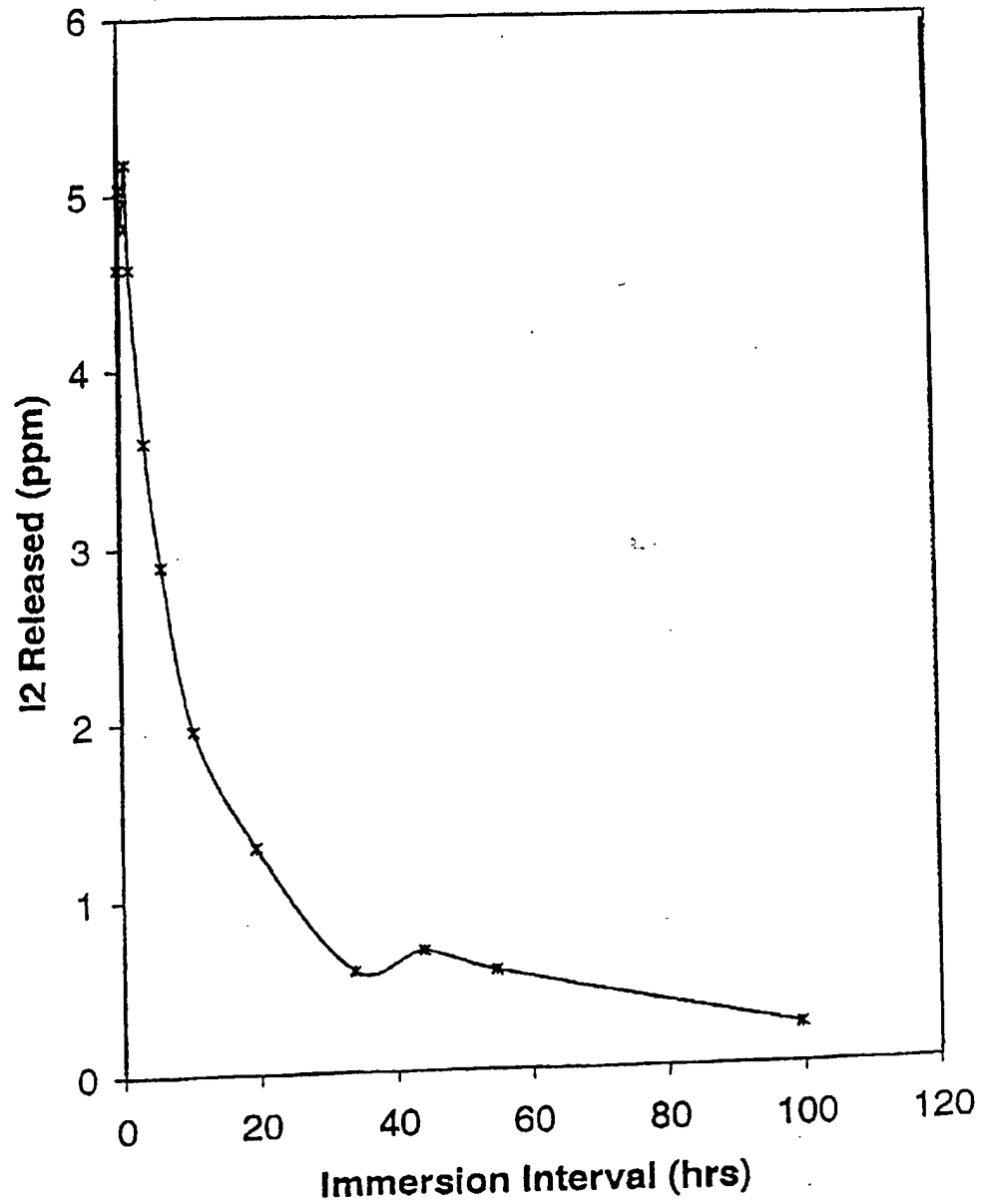
Figure 2





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Figure 3



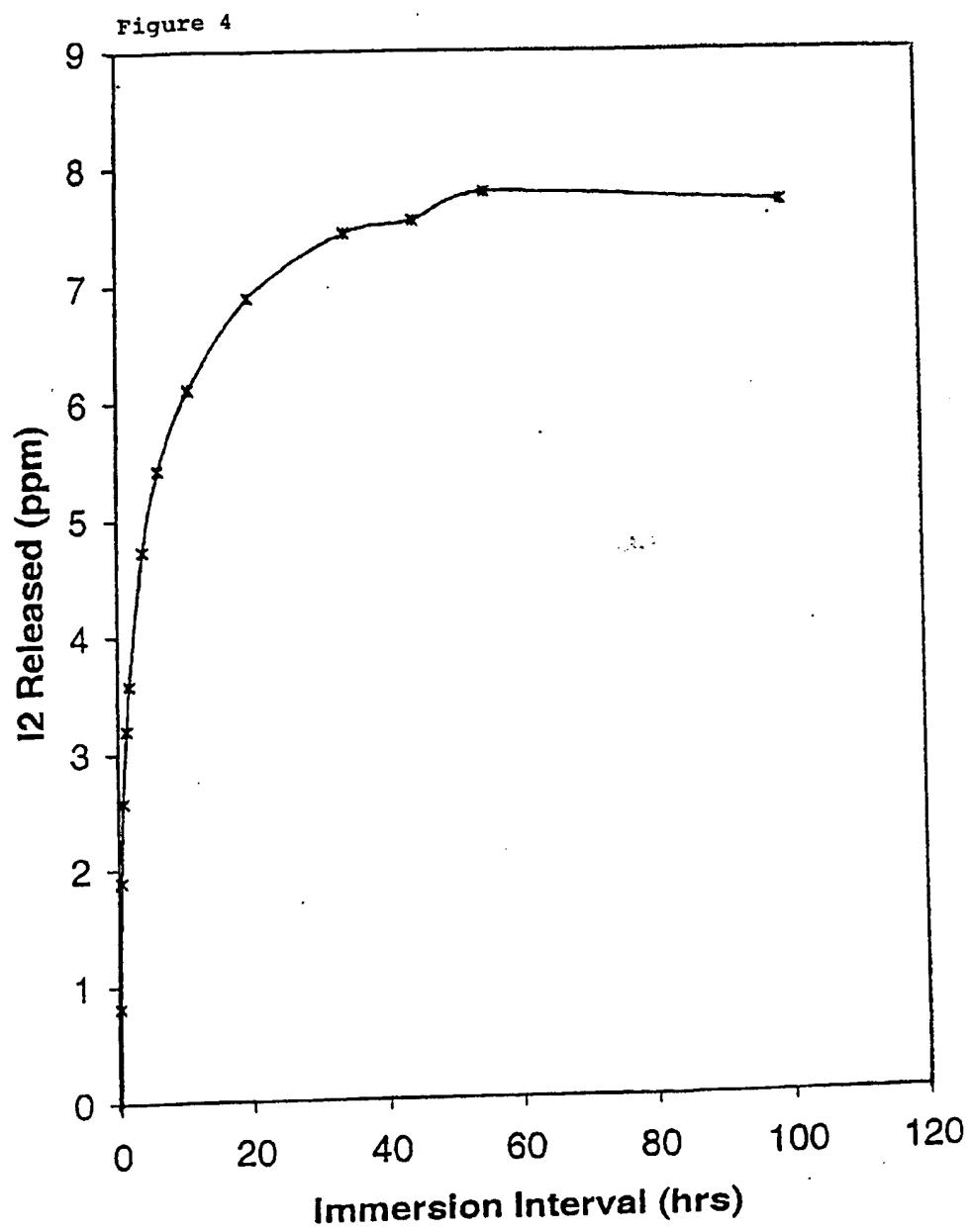


Figure 5

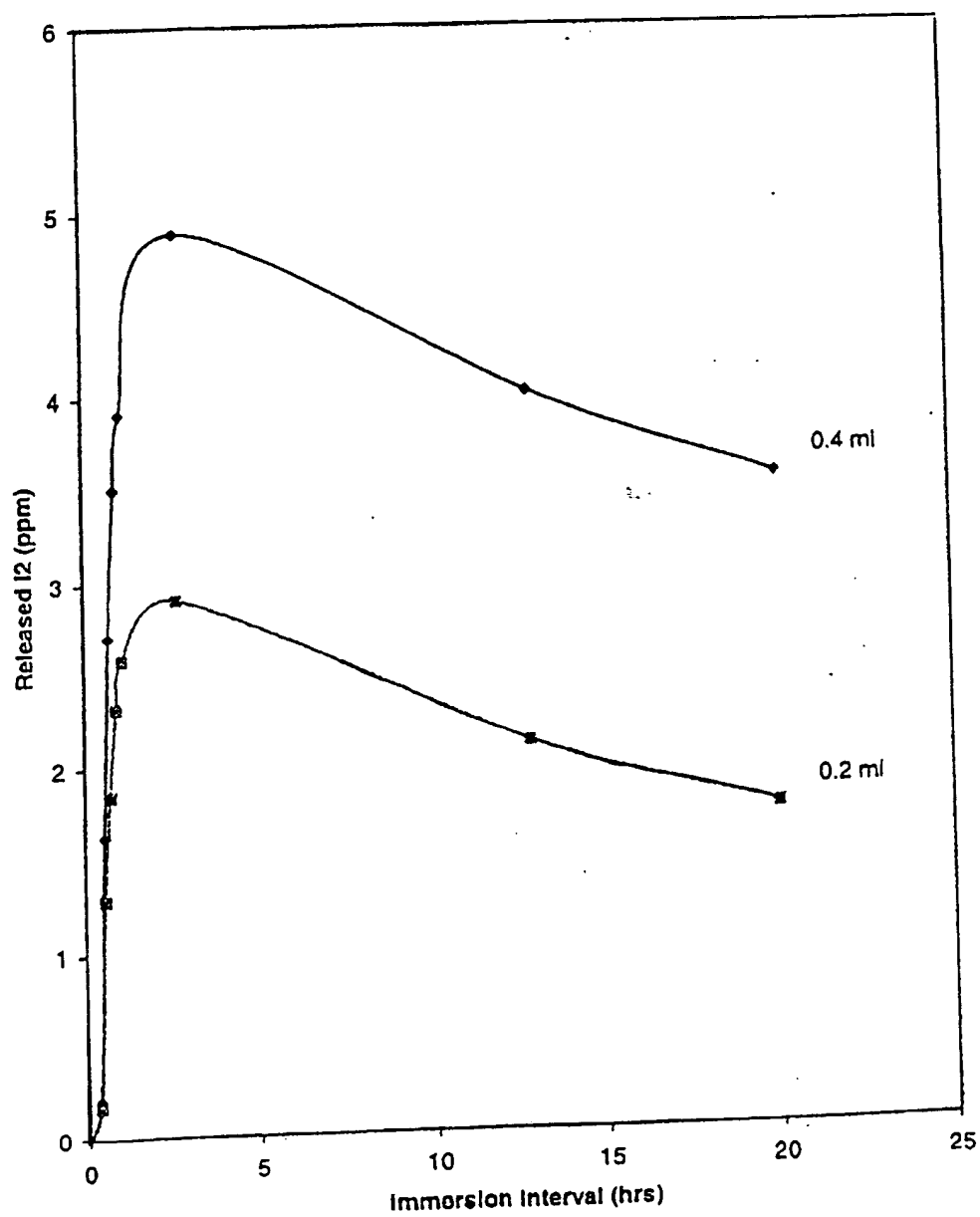
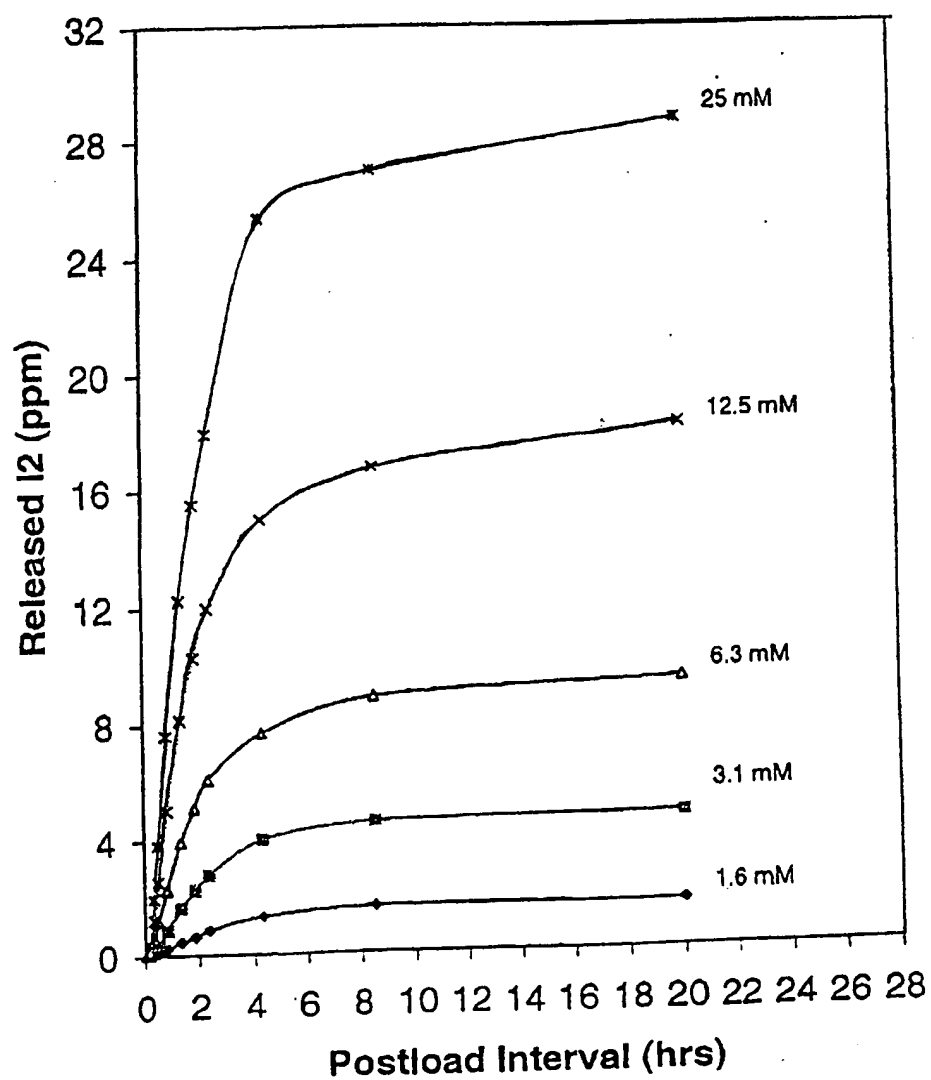
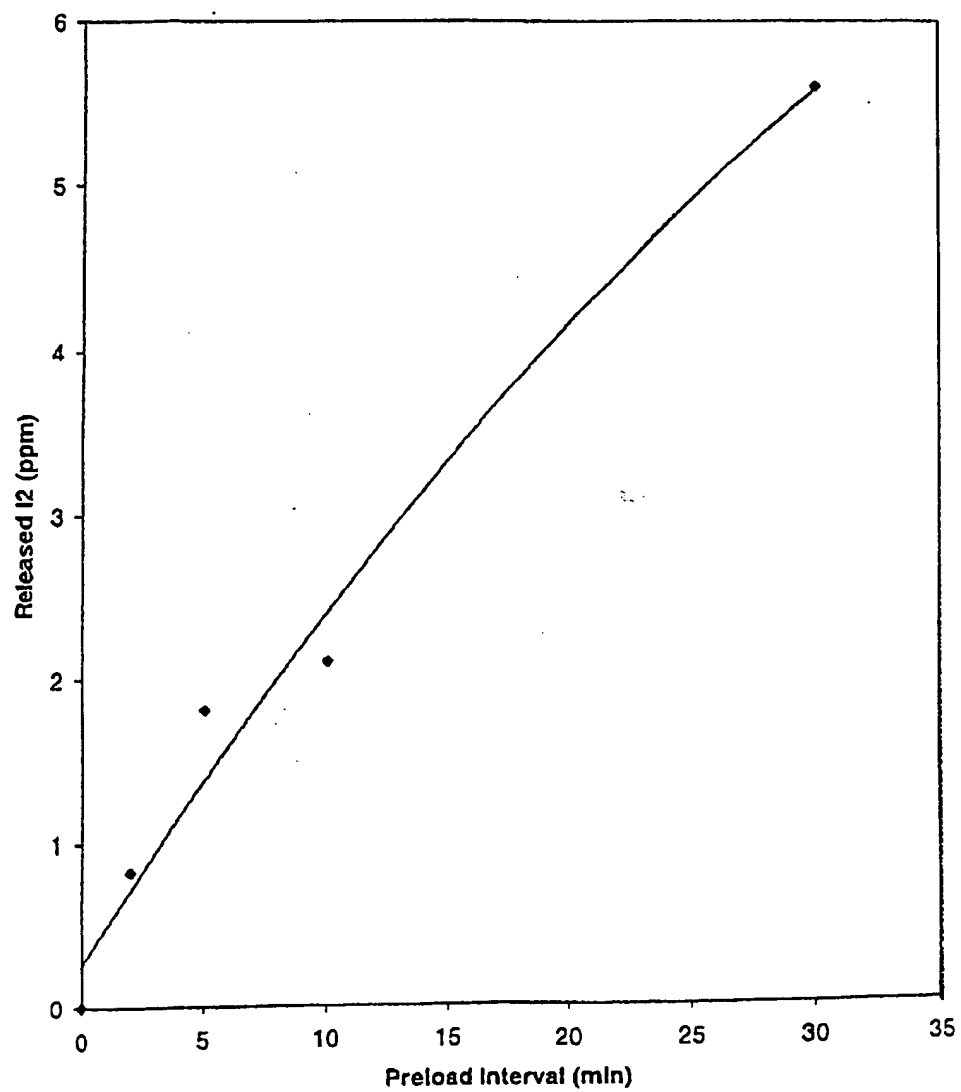


Figure 6



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Figure 7



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Figure 18

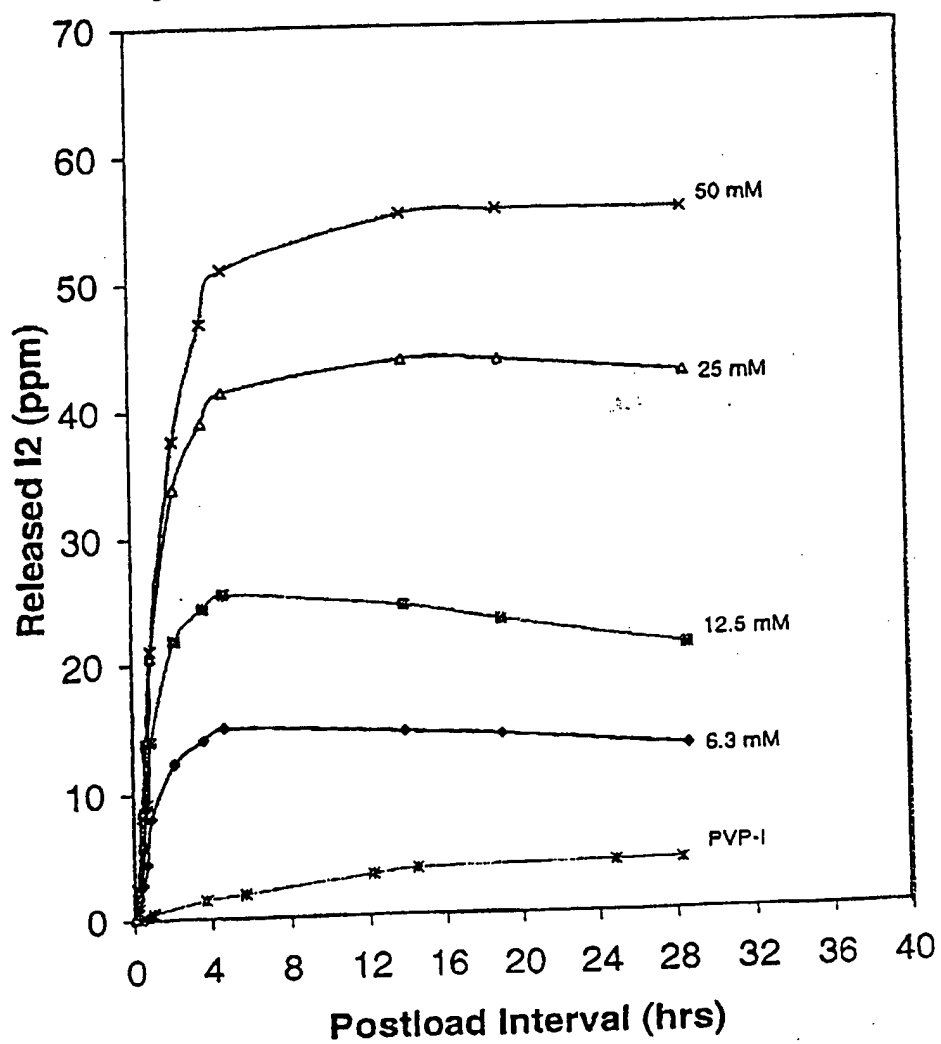
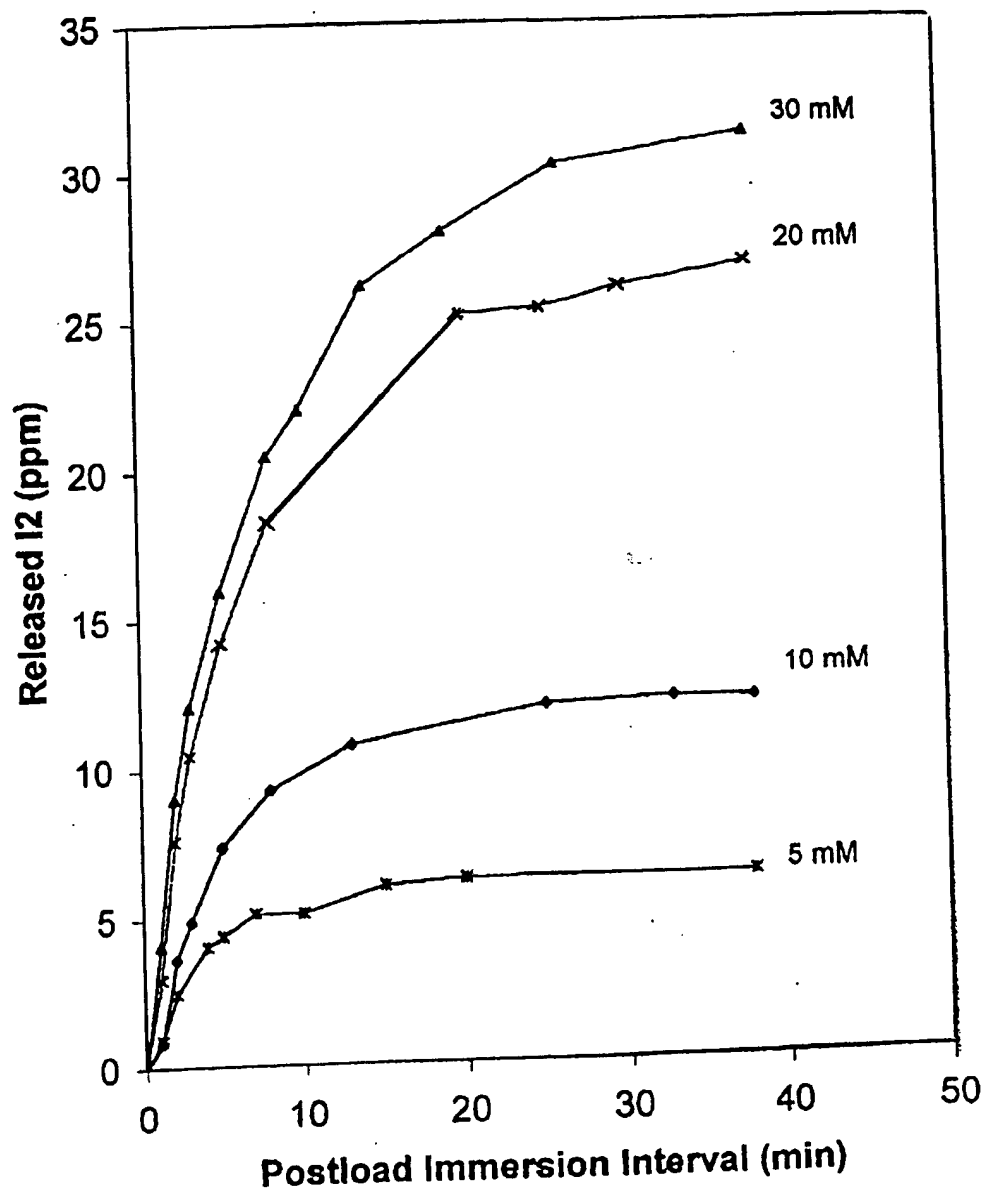
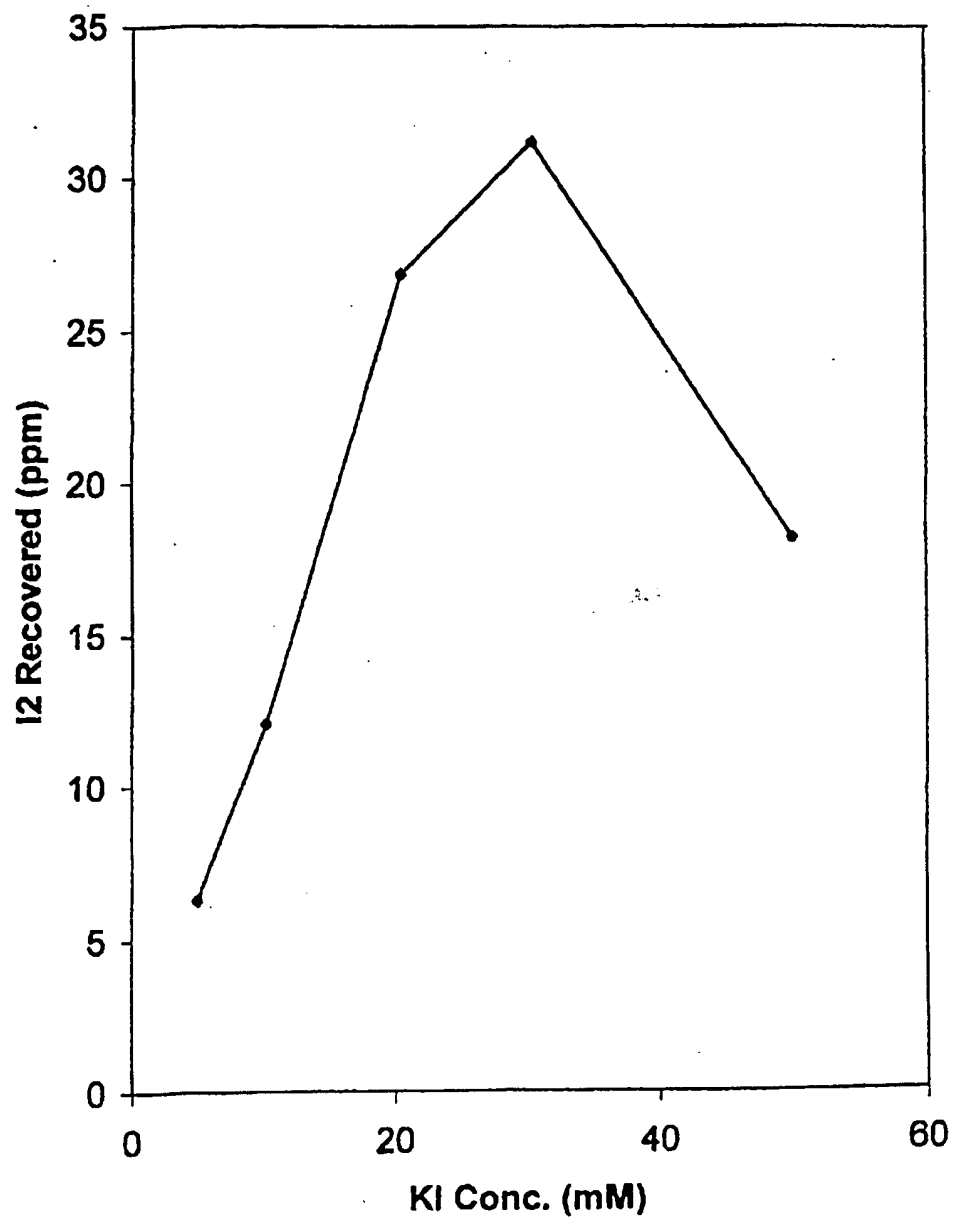


Figure 9



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Figure 10





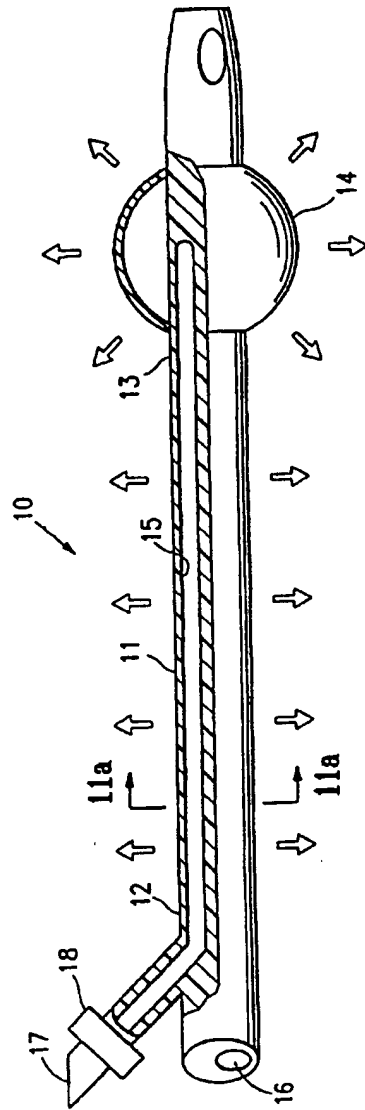


FIG. 11

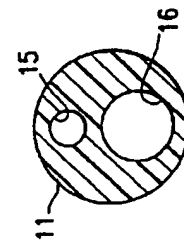


FIG. 11a

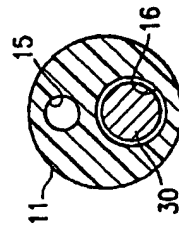


FIG. 11b

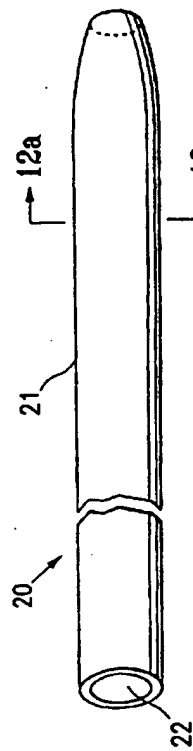


FIG. 12

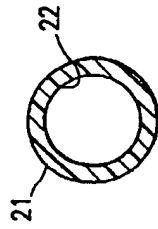


FIG. 12a

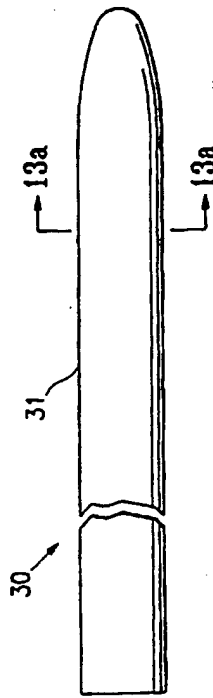


FIG. 13

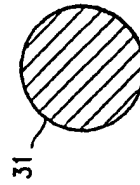


FIG. 13a

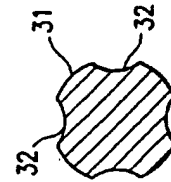
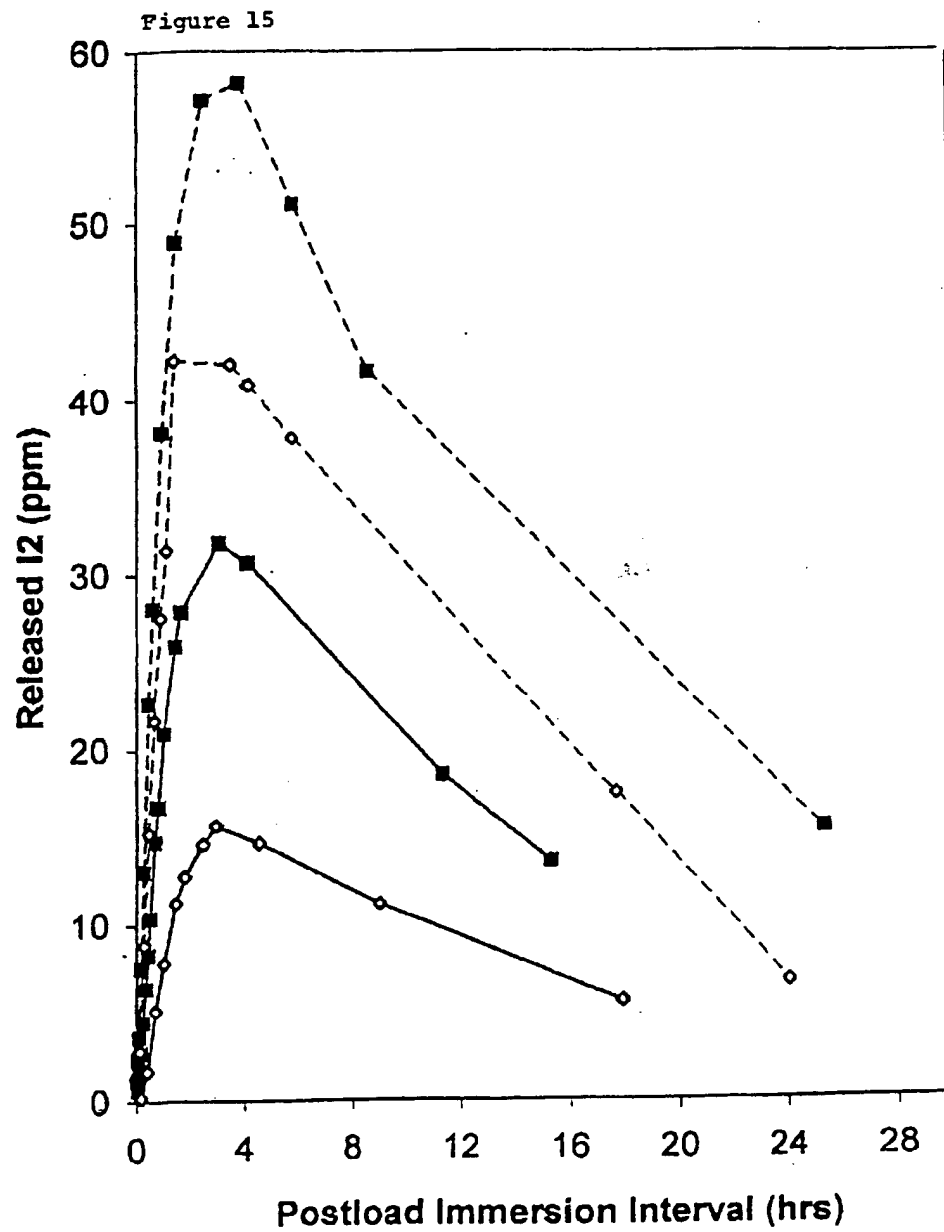
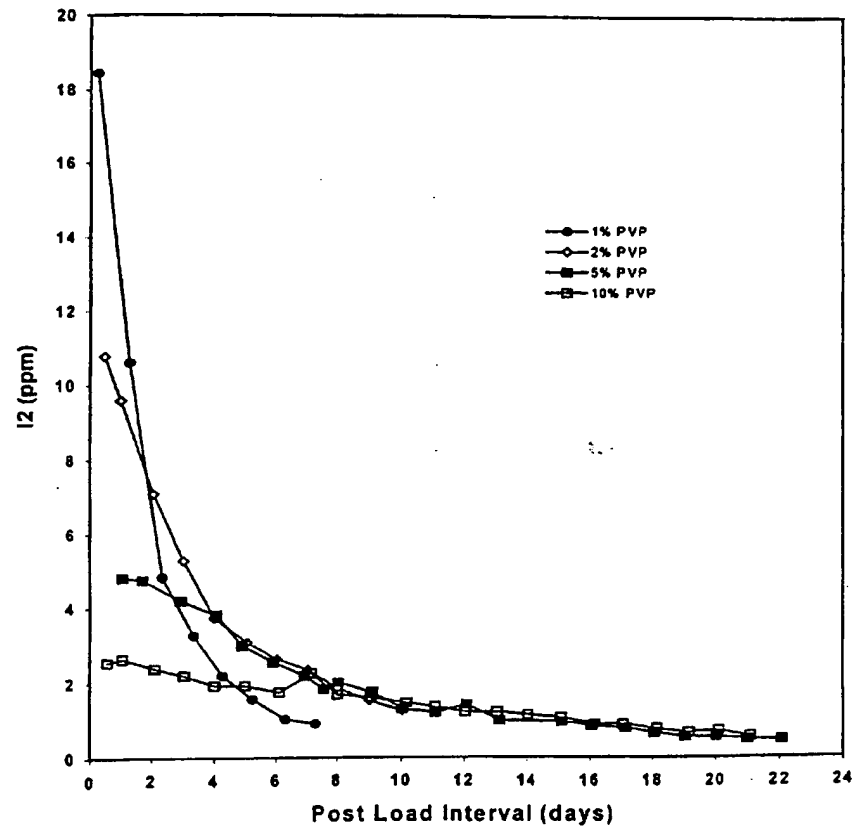


FIG. 14



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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.1

Although claims 1-24,44 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the composition.

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Continuation of Box I.1

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgery

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/15286

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9512316 A	11-05-1995	AU 8001594 A	23-05-1995
WO 9620019 A	04-07-1996	AU 713632 B AU 4422496 A BR 9506910 A CA 2182265 A CN 1142193 A EP 0748233 A JP 9509876 T	09-12-1999 19-07-1996 16-09-1997 04-07-1996 05-02-1997 18-12-1996 07-10-1997
WO 9638548 A	05-12-1996	US 5756090 A AU 708557 B AU 5740196 A CA 2222964 A EP 0832198 A JP 11506444 T US 6033662 A	26-05-1998 05-08-1999 18-12-1996 05-12-1996 01-04-1998 08-06-1999 07-03-2000
US 5648075 A	15-07-1997	US 5639481 A US 5849291 A	17-06-1997 15-12-1998
EP 0747062 A	11-12-1996	AU 722246 B AU 5464896 A BR 9602671 A CA 2178458 A CN 1146338 A JP 9100235 A US 6025446 A	27-07-2000 19-12-1996 06-10-1998 08-12-1996 02-04-1997 15-04-1997 15-02-2000
WO 9324132 A	09-12-1993	BR 9207111 A US 5232914 A AU 2145192 A EP 0642346 A JP 10511927 T	12-12-1995 03-08-1993 30-12-1993 15-03-1995 17-11-1998
US 5558881 A	24-09-1996	AU 683040 B AU 5905794 A CA 2119918 A FR 2702930 A GB 2276546 A, B NZ 260178 A	30-10-1997 29-09-1994 27-09-1994 30-09-1994 05-10-1994 26-03-1996
WO 9965538 A	23-12-1999	AU 4699799 A	05-01-2000

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 00/15286

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61L27/54 A61L29/16 A61L31/16 A61L2/18 //A61L101:06,  
A61L101:08,A61L101:20,A61L101:36,A61L101:48,A61L101:54

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61L A01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95 12316 A (DUNCAN GROUP PLC ;KELEMEN MARY VIKTORIA (GB)) 11 May 1995 (1995-05-11)  page 1, line 34 -page 2, line 4 claims	1,2,4,8, 11,12, 17-20, 32-44
X	WO 96 20019 A (BAXTER INT) 4 July 1996 (1996-07-04)  page 10, line 24 - line 30 figures 4-6 claims 1-6,16-26  -/-	1,2, 17-20, 40-44

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"Z" document member of the same patent family

Date of the actual completion of the international search

10 October 2000

Date of mailing of the international search report

17/10/2000

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## INTERNATIONAL SEARCH REPORT

Internat. Application No.  
PCT/US 00/15286

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 96 38548 A (EXOXEMIS INC ;ALLEN ROBERT C (US)) 5 December 1996 (1996-12-05)  page 10, line 10 - line 14 claims	1,2,4,9, 12, 17-20, 32-44
Y	US 5 648 075 A (KESSLER JACK H ET AL) 15 July 1997 (1997-07-15)  column 4, line 12 - line 45 claims	1,2,4,9, 12, 17-20, 32-44
A	EP 0 747 062 A (JOHNSON & JOHNSON CONSUMER) 11 December 1996 (1996-12-11)  page 2, line 44 - last line example 9 figure 1	1,2,4,7, 12,17, 18, 21-23, 32-44
A	WO 93 24132 A (EPITOPE INC ;FELLMAN JACK H (US)) 9 December 1993 (1993-12-09)  column 6, line 1 - line 20 claims	1,2,4,8, 11-20, 32-44
A	US 5 558 881 A (CORBY MICHAEL P) 24 September 1996 (1996-09-24)  examples claims	1,2,4,8, 11-19, 21,32-44
P,X	WO 99 65538 A (OXIBIO INC) 23 December 1999 (1999-12-23)  page 33, line 13 - line 23 claims	1,2, 4-25, 30-44